

# Climate Change is Here: Tipping Points & Rays of Hope

Evan Mills

Staff Scientist

U.S. Department of Energy

Lawrence Berkeley National Laboratory









# The Scientific Consensus

Intergovernmental Panel  
on Climate Change

**1300 Authors; 1100 Reviewers  
Unanimously adopted by 100+  
nations (including U.S.)**



# Federal Government

**“By increasing the levels of greenhouse gases in the atmosphere, human activities are strengthening Earth's natural greenhouse effect.”**

- U.S. Environmental Protection Agency

# Local Governments

**The mayors of more than 200 cities in 38 states have signed the “U.S. Mayors Climate Protection Agreement,” urging Congress to pass federal climate legislation and pledging to meet or better Kyoto targets in their own communities.**

# The Business World

**In a survey completed by 354 of the *Financial Times Global 500* companies, more than 90 percent cited climate change as posing commercial risks and/or opportunities**

# Insurance Industry

**“We'd be out of our minds if we wrote weather insurance on the opinion global warming would have no effect at all.”**

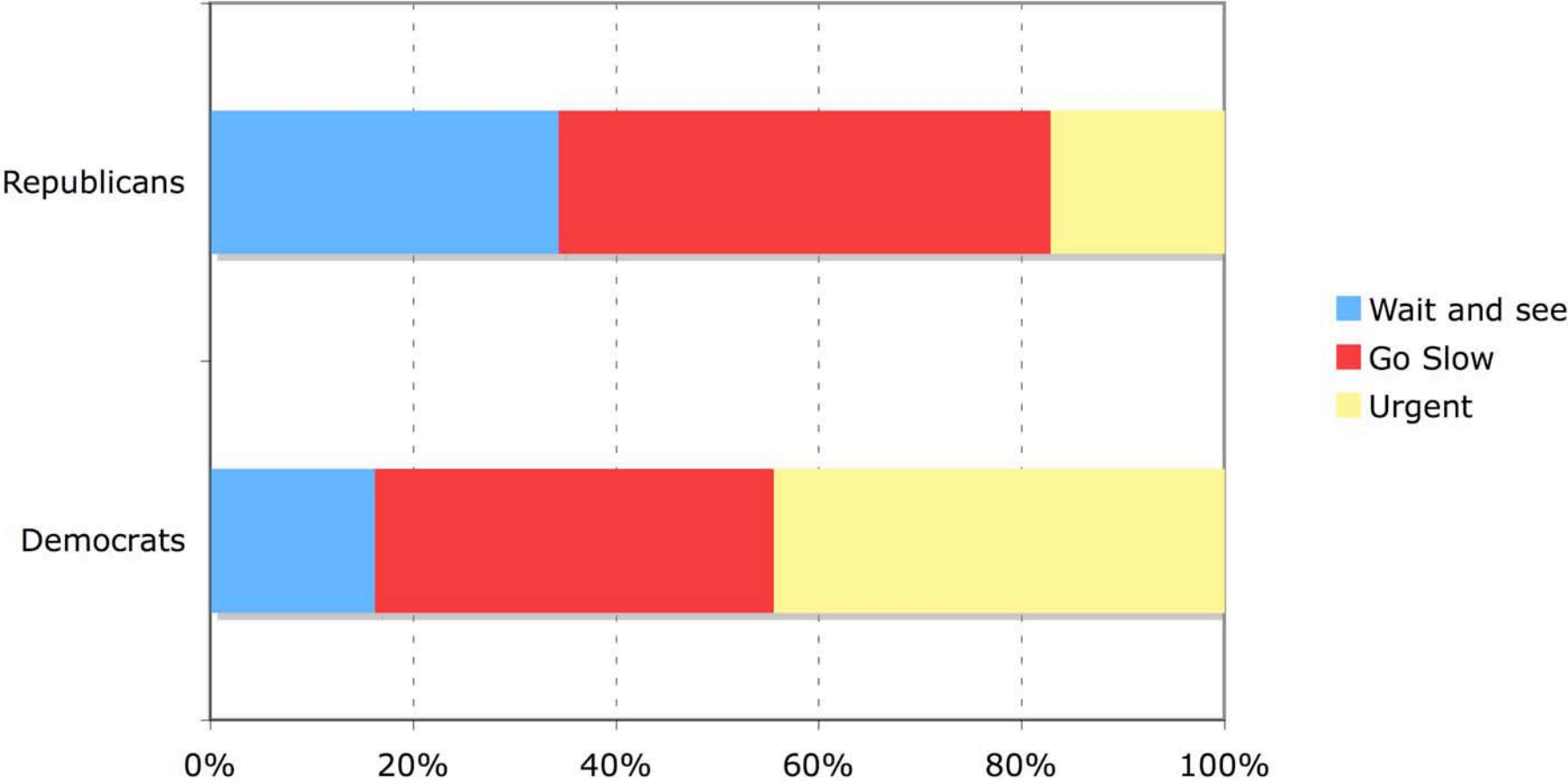
- Warren Buffett  
2006 annual Shareholder meeting



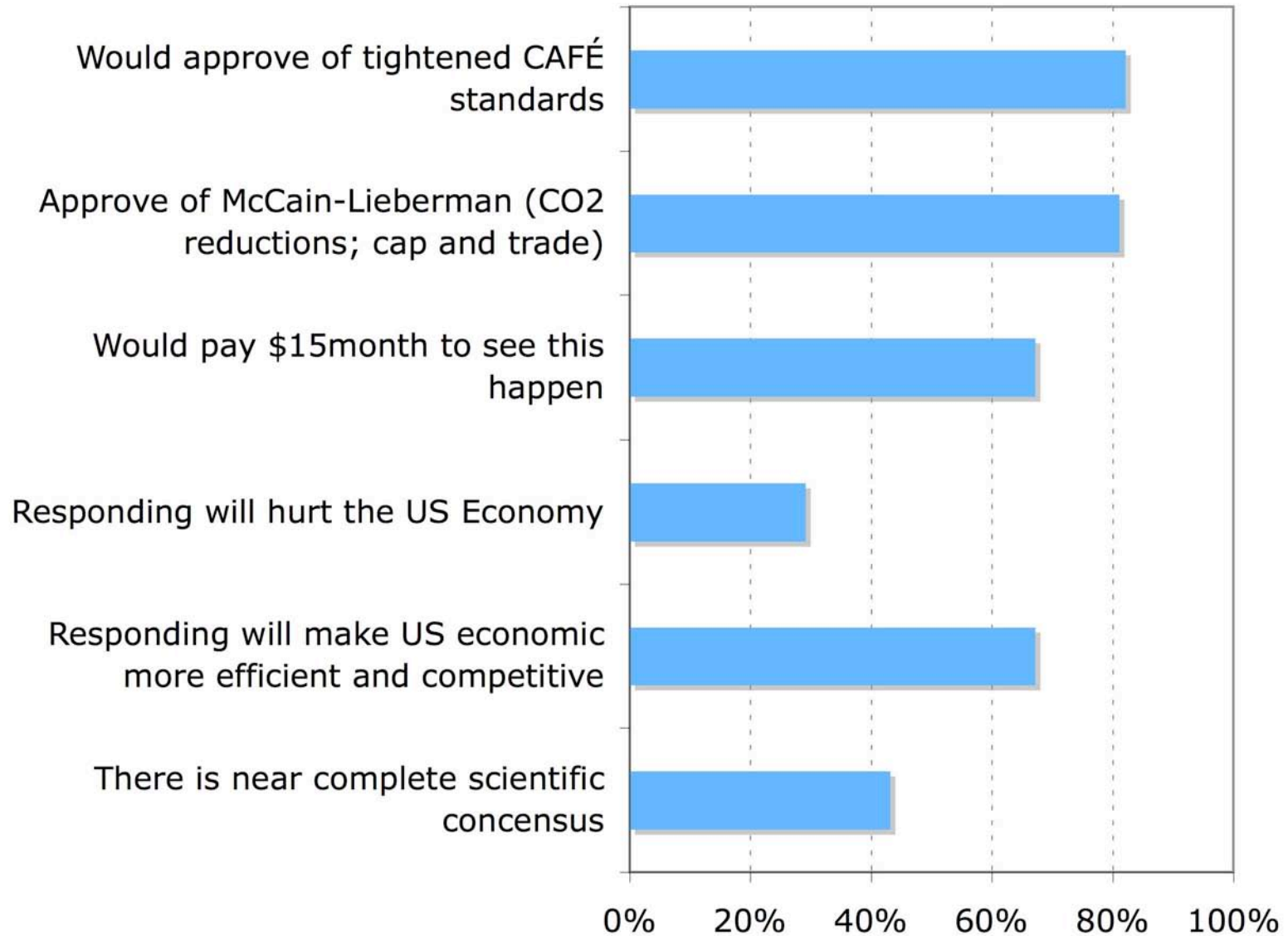


- James Woolsey - Former CIA Director  
Prius' bumper sticker reads:  
*“Osama bin laden hates this car.”*
- Richard Cizik - National Assoc. of Evangelicals  
“Pollution from cars and power plants is  
destroying God's creation... it violates  
sanctity of life.”

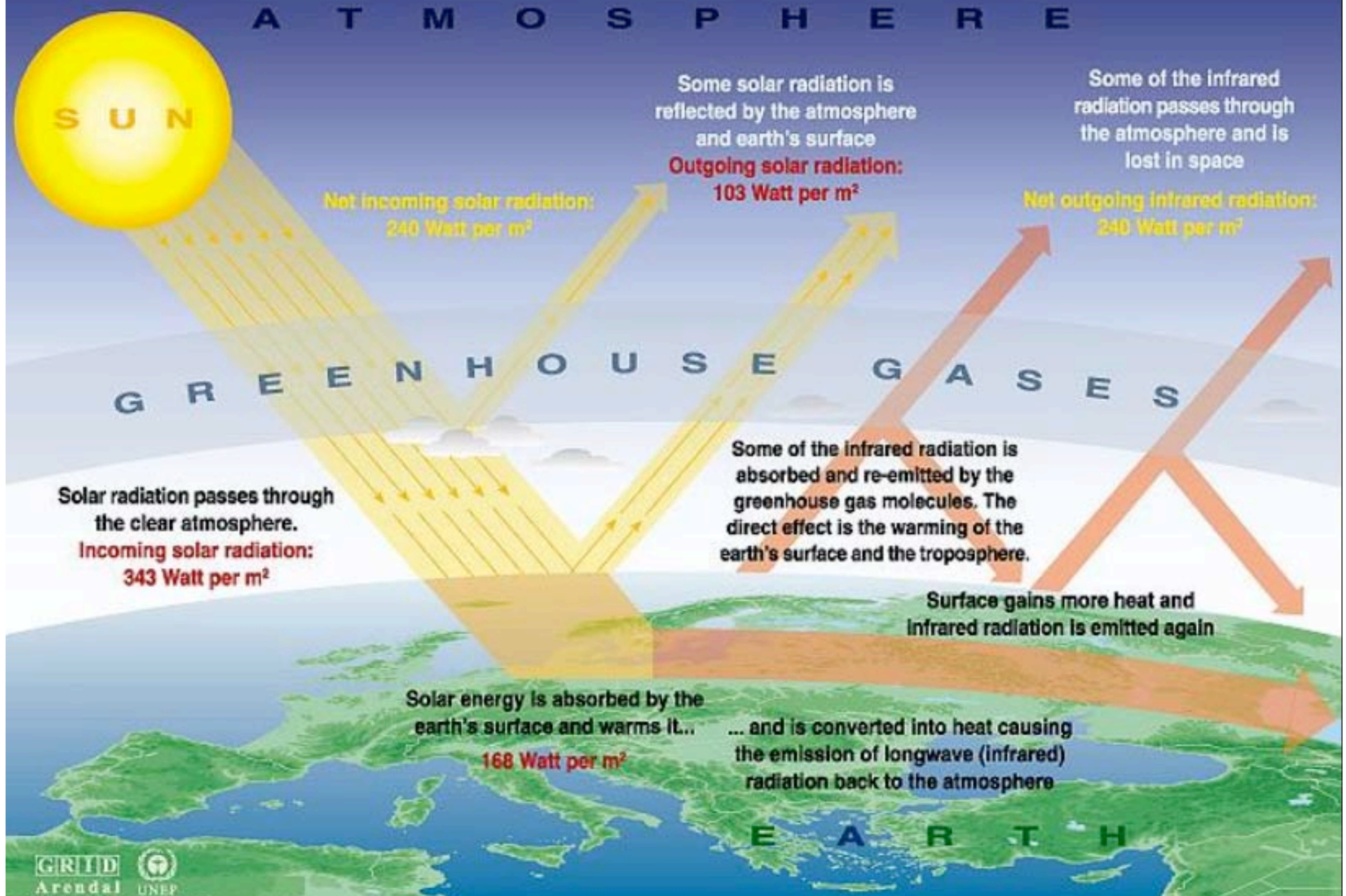
# Climate Change Views by Party Association (2004)



## Public Opinion on Climate Change (June 2004)

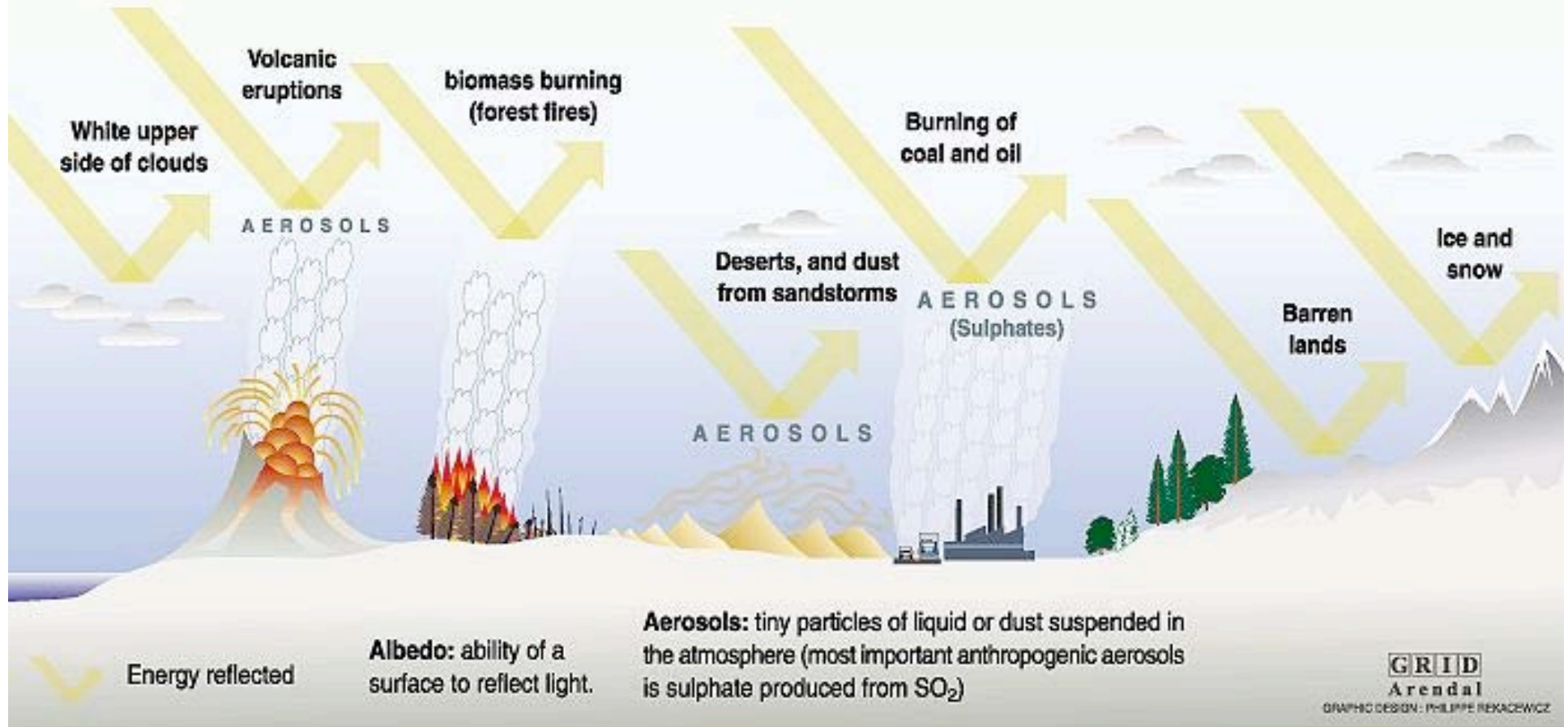


# The Greenhouse effect





## The cooling factors



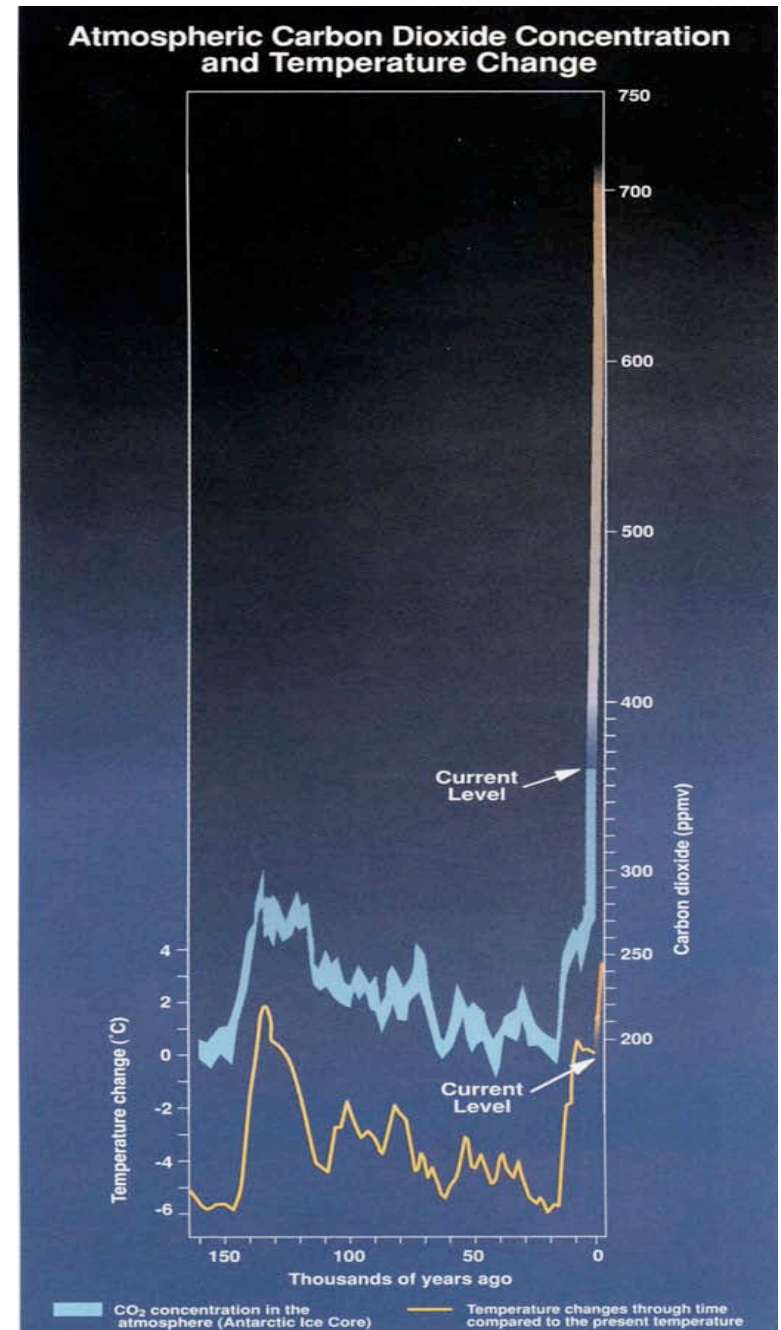
Sources: Radiative forcing of climate change, the 1994 report of the scientific assessment working group of IPCC, summary for policymakers, WMO, UNEP; L.D. Danny Harvey, Climate and global environmental change, Prentice Hall, Pearson Education, Harlow, United Kingdom, 2000.

Source: United Nations - Intergovernmental Panel on Climate Change

# Vostok Ice Cores:



150,000 years of  
carbon and  
temperature





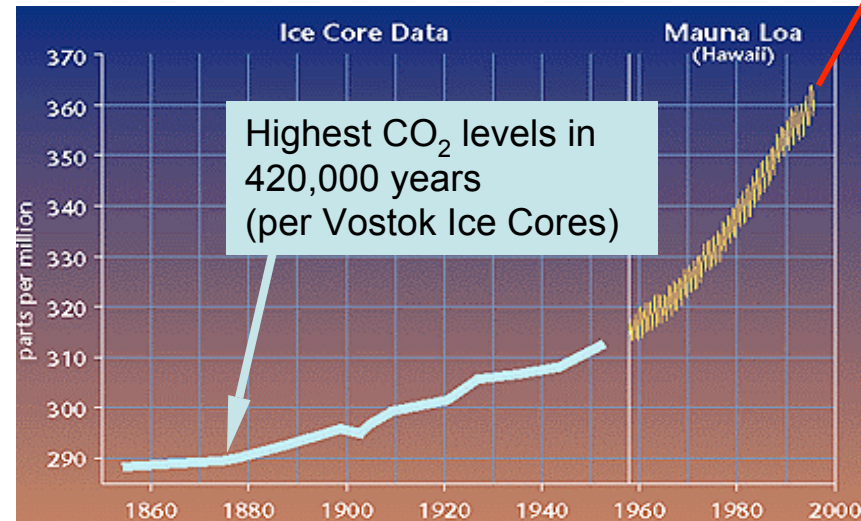
# The Primary Human Influence is Fossil Fuels Combustion



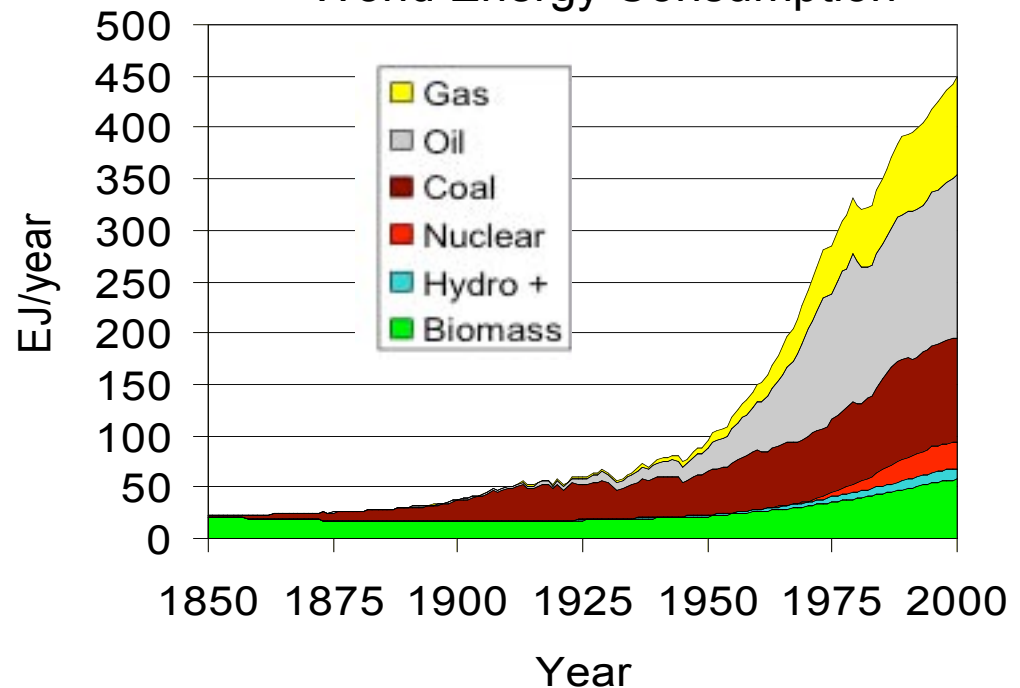
(Second is Deforestation)

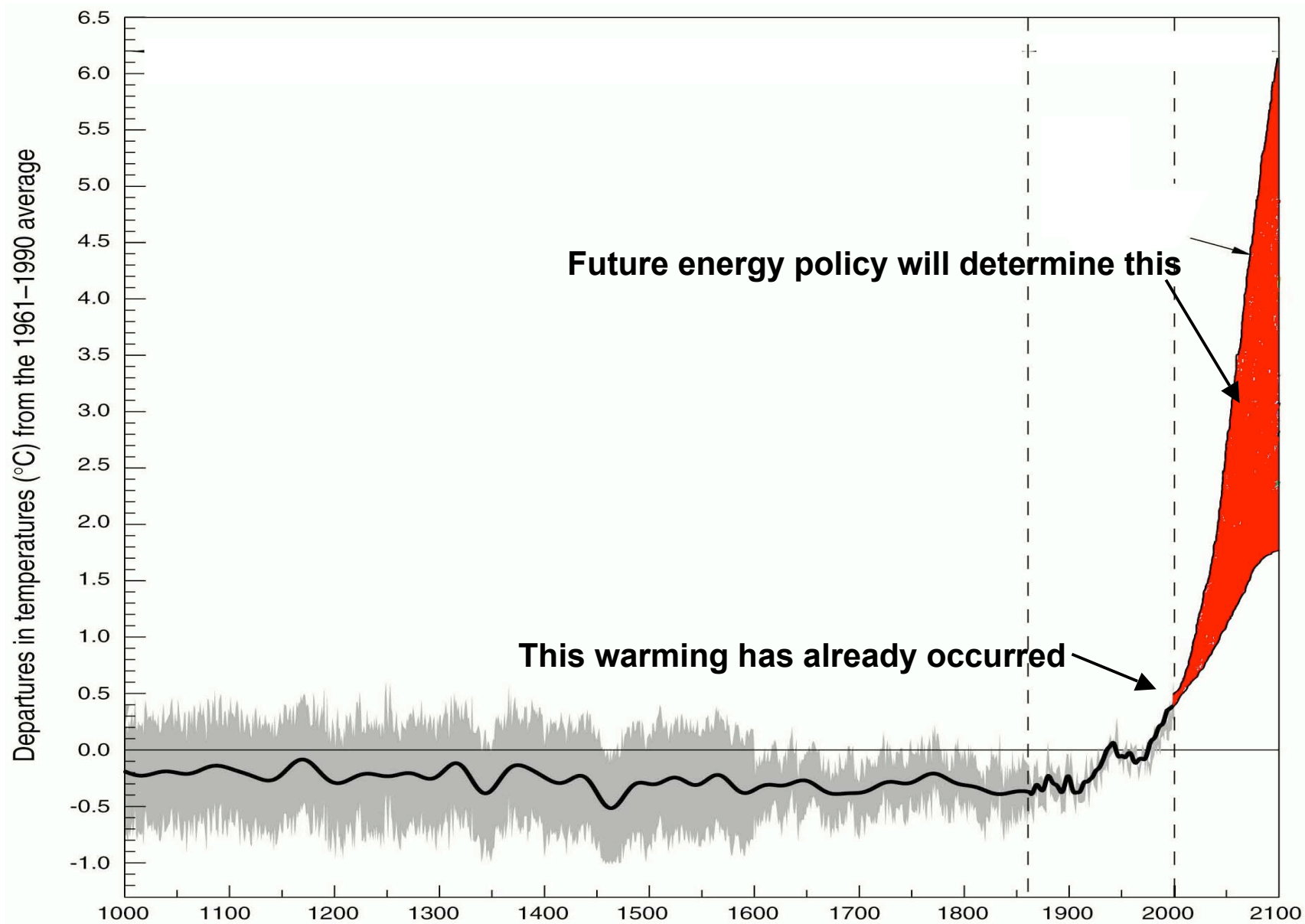


## World Carbon Dioxide Concentrations



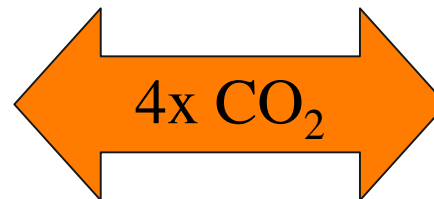
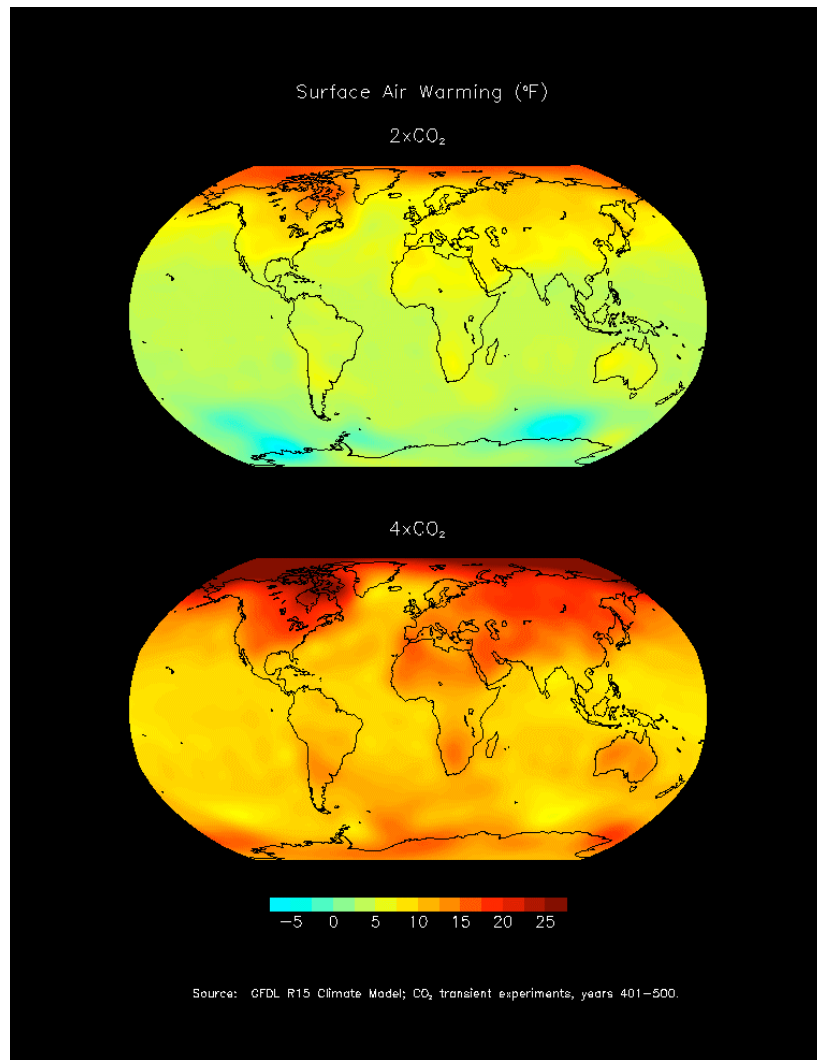
## World Energy Consumption





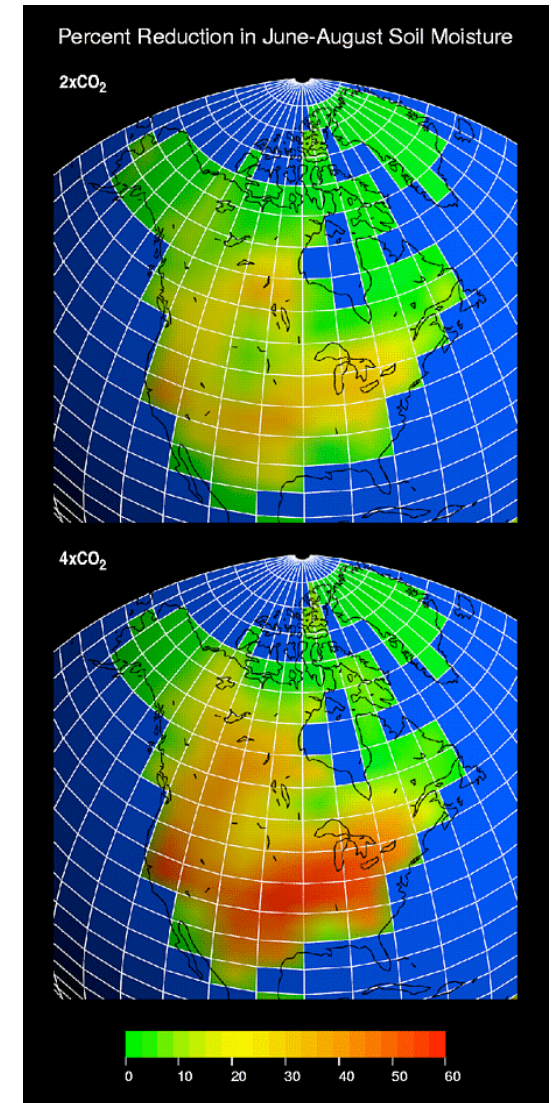
# We'll pass the 2xCO<sub>2</sub> Milestone ~2050

## Air Temperatures



**With increased  
warming, net  
impacts become  
increasingly  
negative**

## Soil Moisture



Source: NOAA (Geophysical Fluid Dynamics Laboratory)

# Climate change affects all aspects of life

## Physical Processes

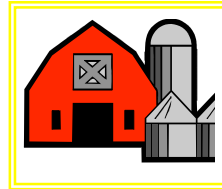
- Air & water temperatures
- Ice
- Precipitation
- Soil moisture
- Ocean currents
- Sea level
- Permafrost
- Weather

## Human Relevance



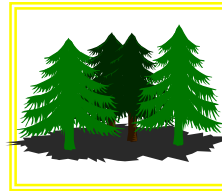
### Health Impacts

Weather-related mortality/heat stress  
Infectious diseases  
Air quality-induced respiratory effects



### Agriculture Impacts

Crop yields and commodity prices  
Irrigation demands  
Pests and weed



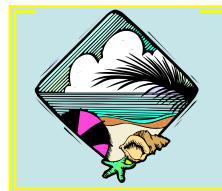
### Forest Impacts

Change in forest composition  
Shift geographic range of forests  
Forest health and productivity



### Water Resource Impacts

Changes in water supply and timing  
Water quality  
Increased competition for water



### Coastal Area Impacts

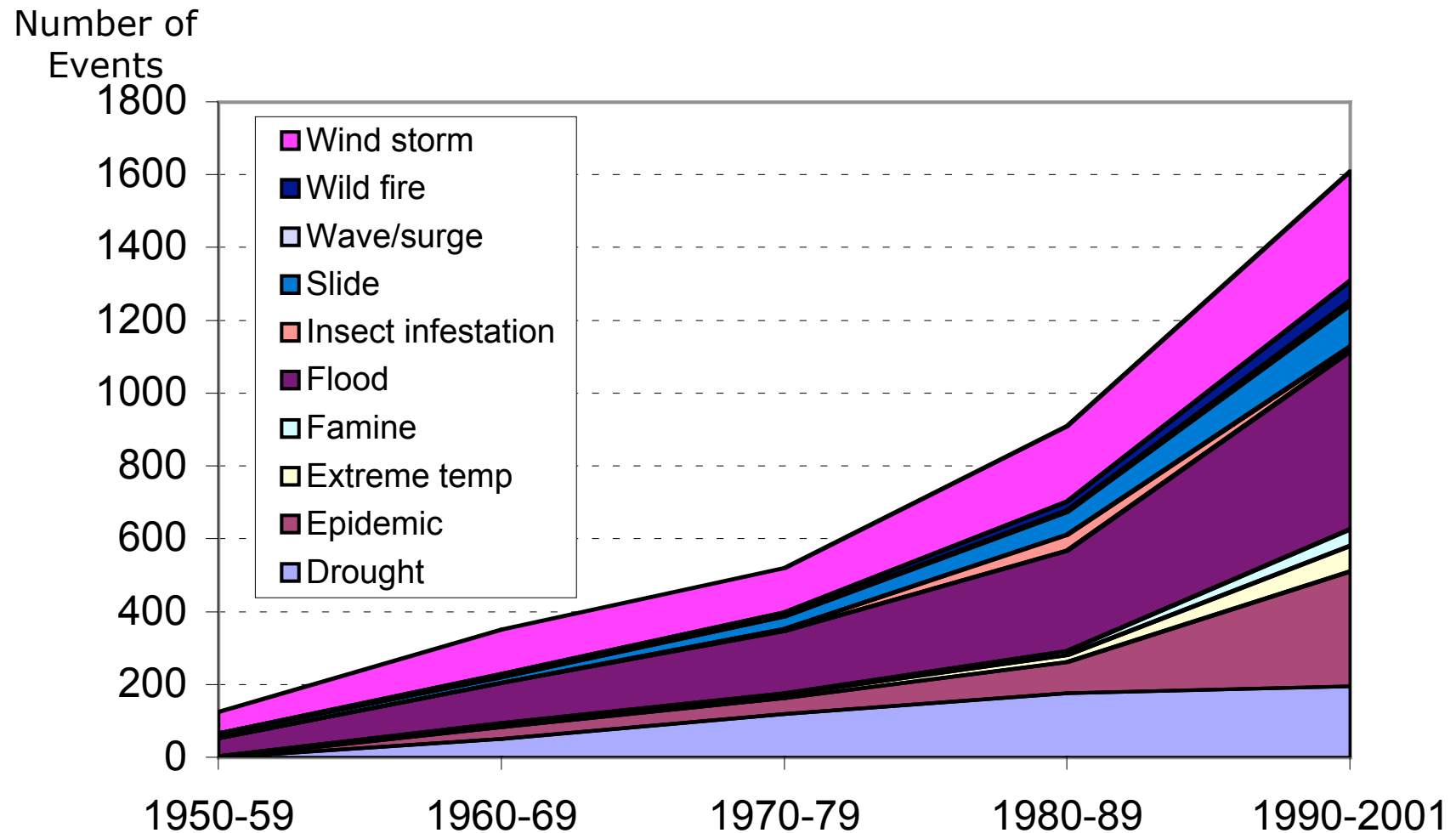
Erosion of beaches  
Inundation of coastal wetlands  
Costs to defend coastal communities



### Ecosystem Impacts

Shifts in ecological zones  
Loss of habitat and species  
Coral reefs threatened

# Fingerprint: Rise in Number and Change in Mix of Weather/Climate Disasters



Source: Center for Research in the Epidemiology of Disasters (CRED)



# Fingerprints

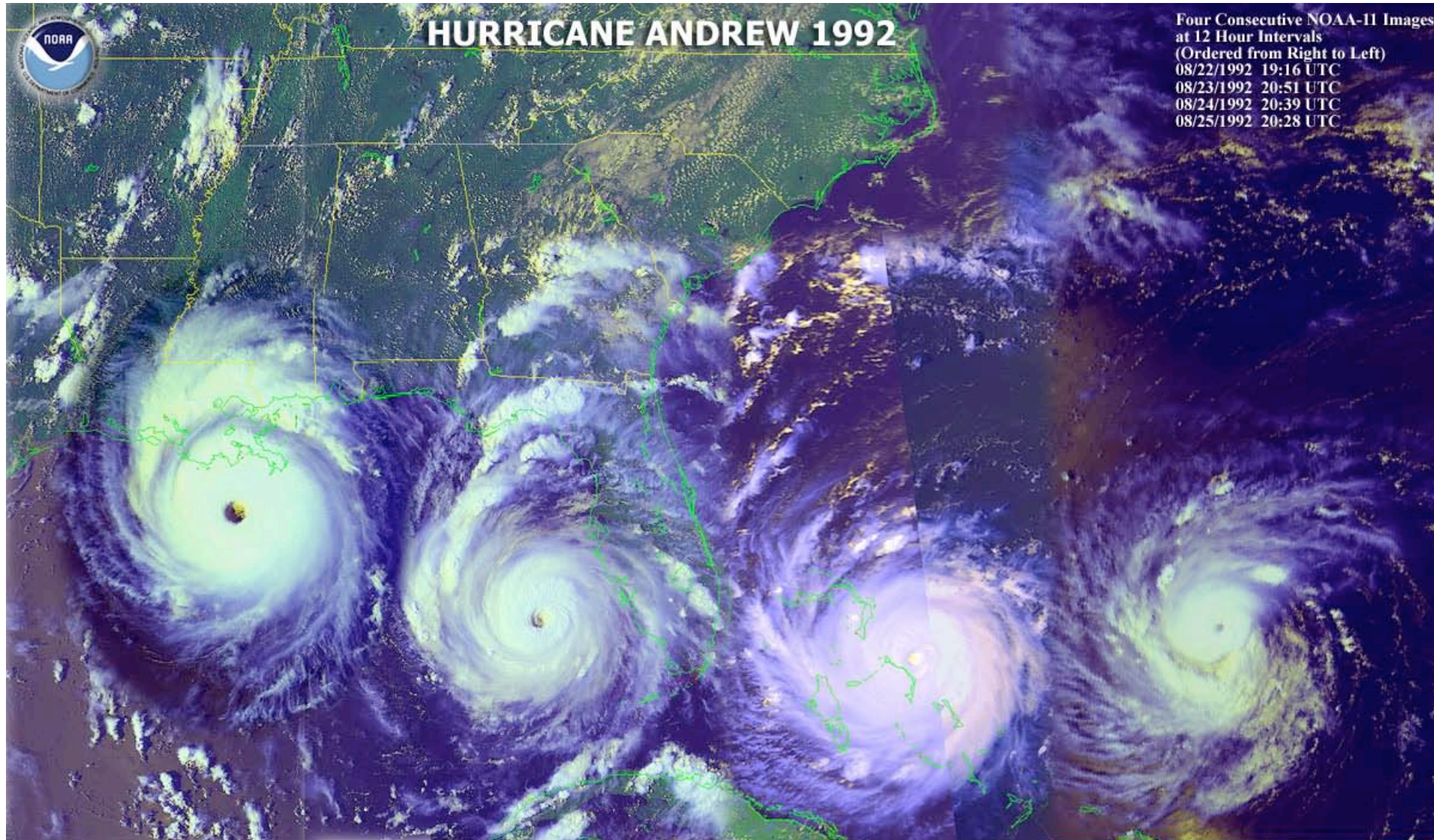




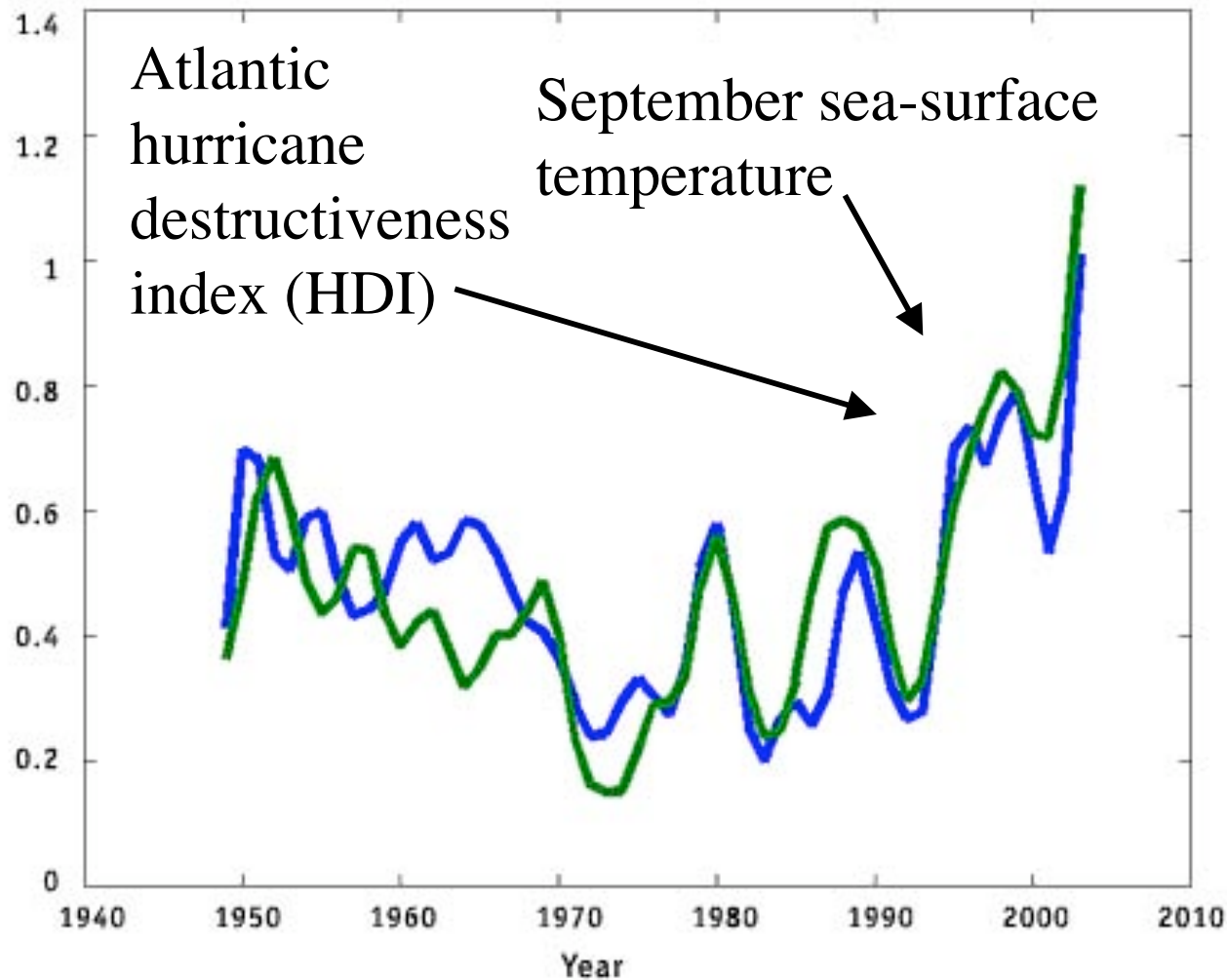


# HURRICANE ANDREW 1992

Four Consecutive NOAA-II Images  
at 12 Hour Intervals  
(Ordered from Right to Left)  
08/22/1992 19:16 UTC  
08/23/1992 20:51 UTC  
08/24/1992 20:39 UTC  
08/25/1992 20:28 UTC



# Hurricane destructiveness increasing in lockstep with ocean temperatures

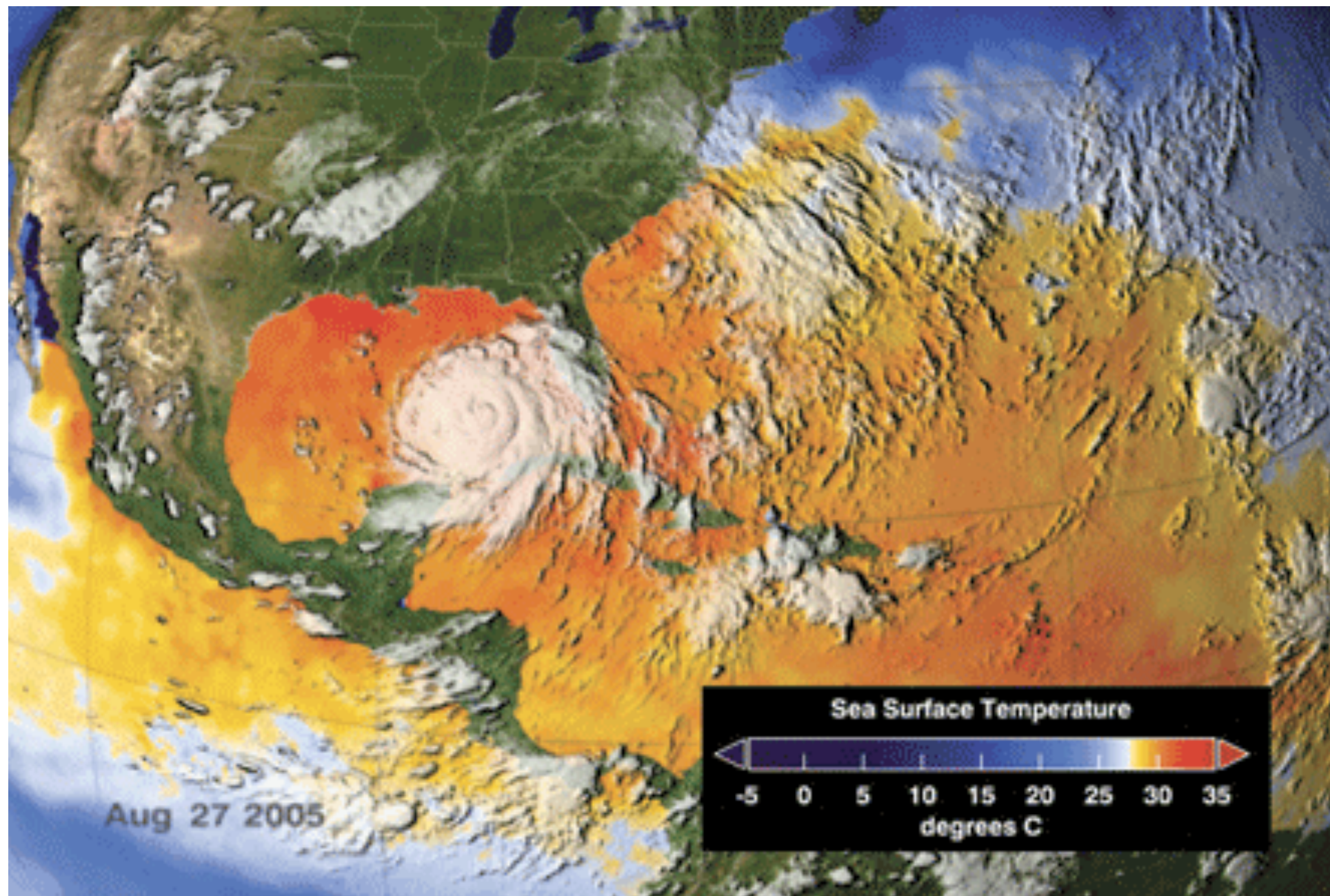


2005 broke most records

- Number
- Strongest storm
- Physical size
- Storm duration
- Season duration
- Southernmost landfall

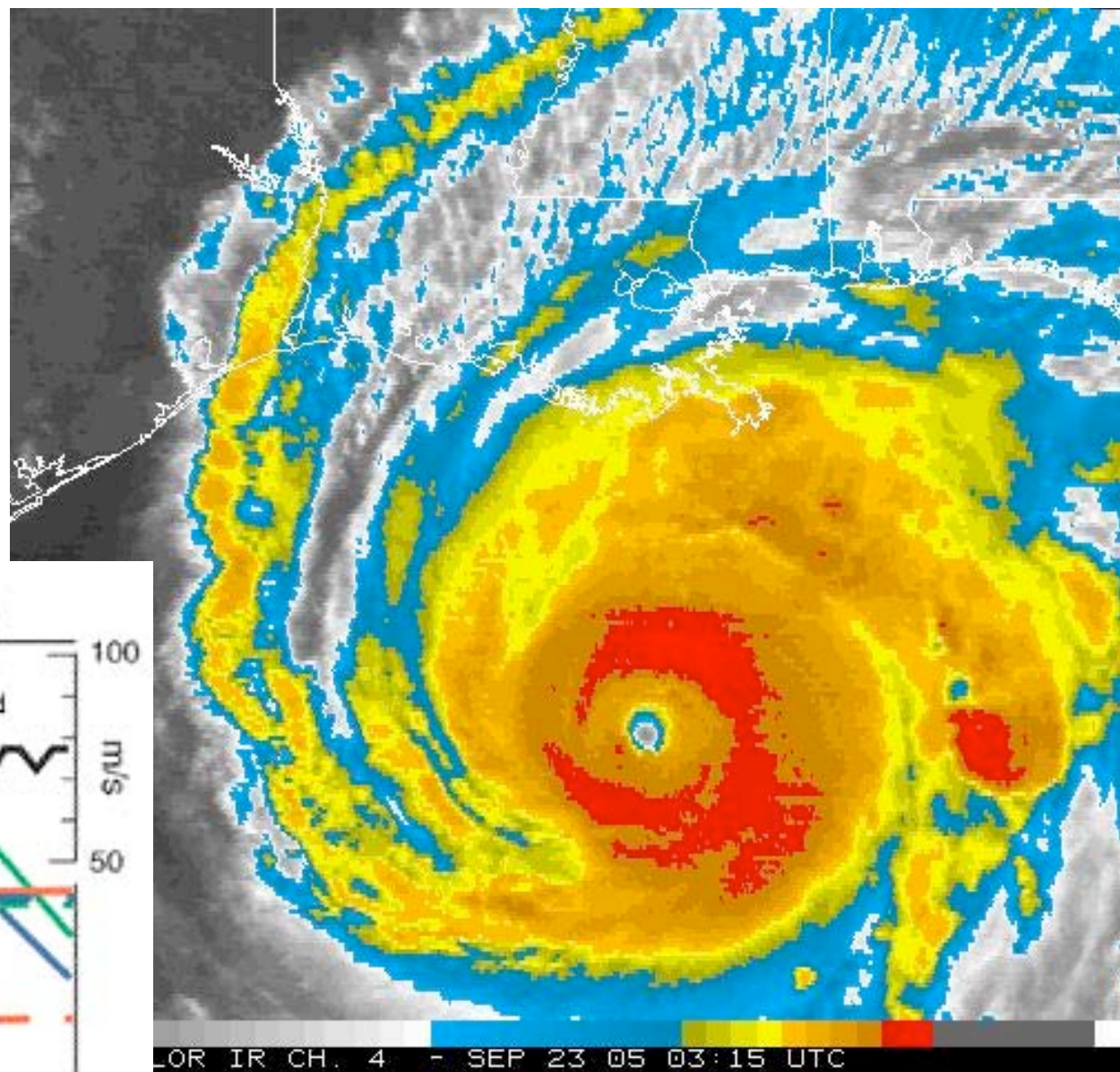
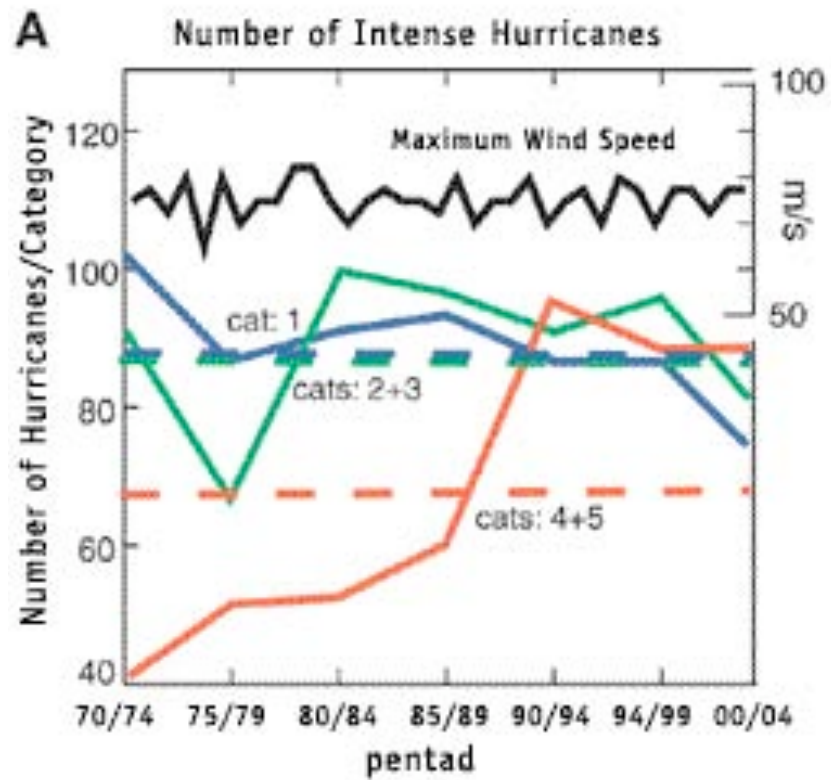
Source: Kerry Emanuel, MIT *Nature* (former “climate skeptic”)







A

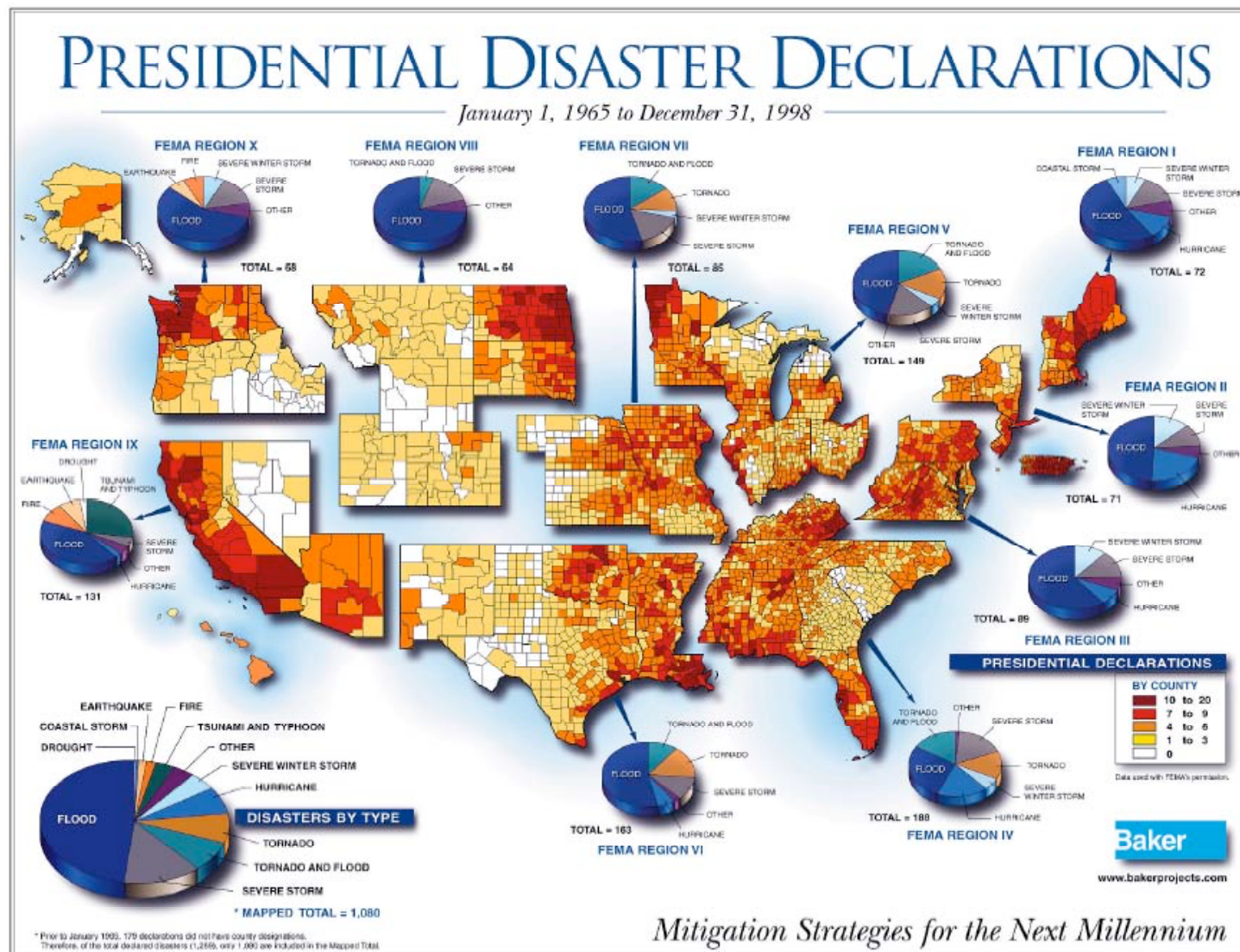






# Disasters Not Just a “Coastal” Issue

~99% Weather Related





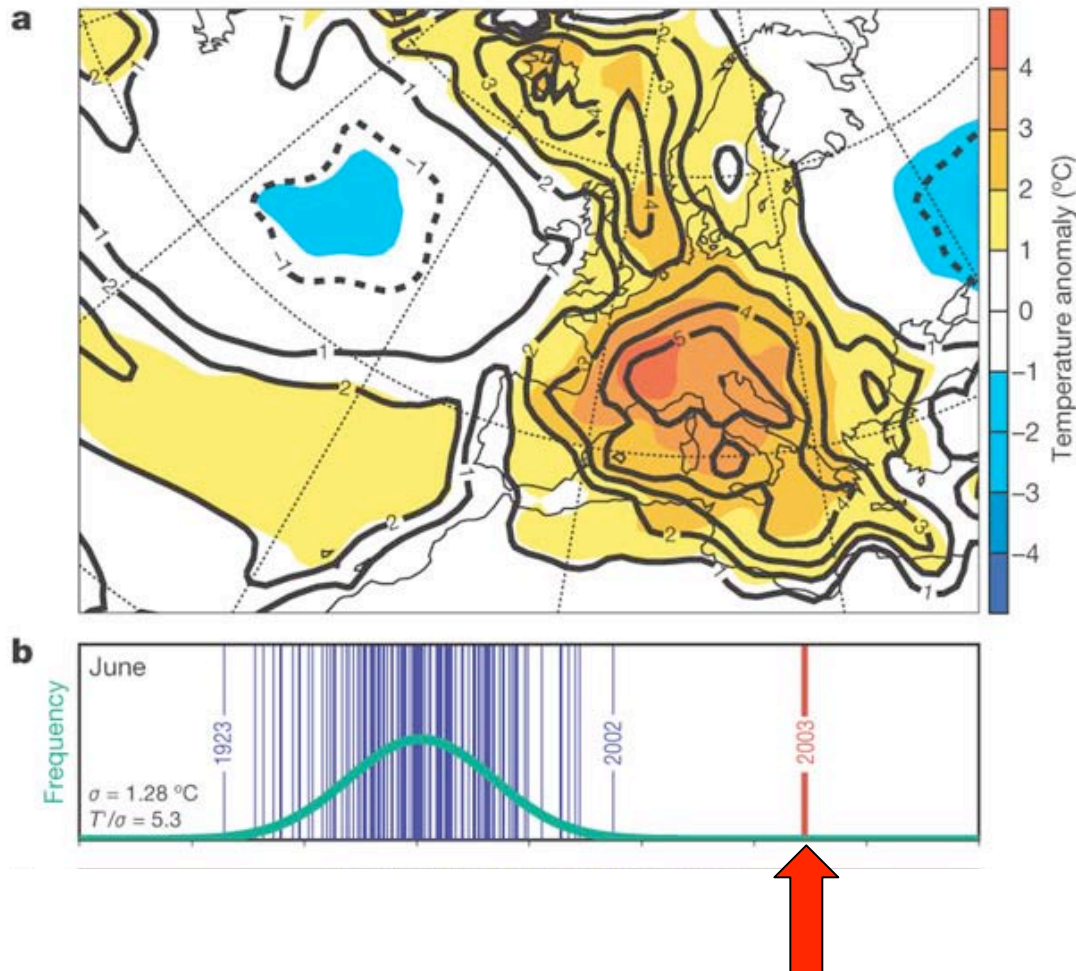
**More Frequent Extremes: For a 1.5 °F temperature increase, the *1-in-300 year heatwave* comes every 10 years.**





# Fingerprint: the 2003 European Heat Wave

(hottest summer since 1500 AD)



Multiple correlated, impacts:

- 22,000-35,000 human fatalities (+unhealthy air masses)
- \$13.6B in crop/livestock losses
- 25,000 fires; 1.2 million acres. \$1.7B in wildfires in Portugal alone + respiratory illness
- Nuclear power plant curtailment (insufficient cooling water)
- Electricity prices 20x US average
- Avalanches (melting permafrost)
- Unhealthy air masses (smog, particulate)

**The European heat wave of Summer 2003**

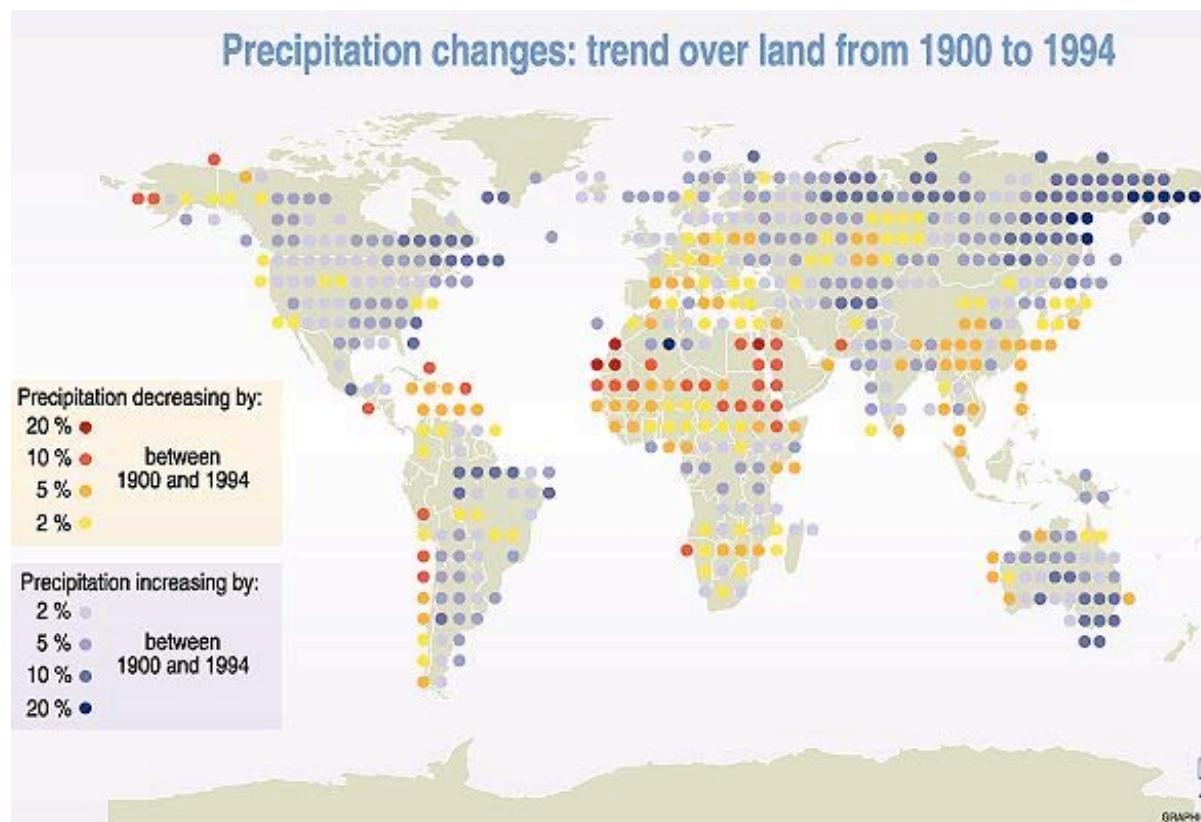
Source: Schar 2004 (*Nature*)

# Small-scale, Gradual, Diffuse, and Indirect Events Often Overlooked

*Greater  
combined  
impacts than  
CATs in an  
average year*

- Blackouts
- Crop damages
- Equipment breakdown
- Eroded air quality
- Eroded water quality
- Hail
- Ice Storms
- Infectious diseases
- Lightning
- Mudslides
- Permafrost melt
- Sea-level rise & coastal erosion
- Sinkholes
- Subsidence
- Thunderstorms
- Tornados
- Vehicle damages/injuries
- Wildfire
- Winterstorms





: Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, 1996; Hulme et al., 1991 and 1994; Global Historical Climate Network (GHCN), Vose et al., 1995 and Eischeid et al., 1995

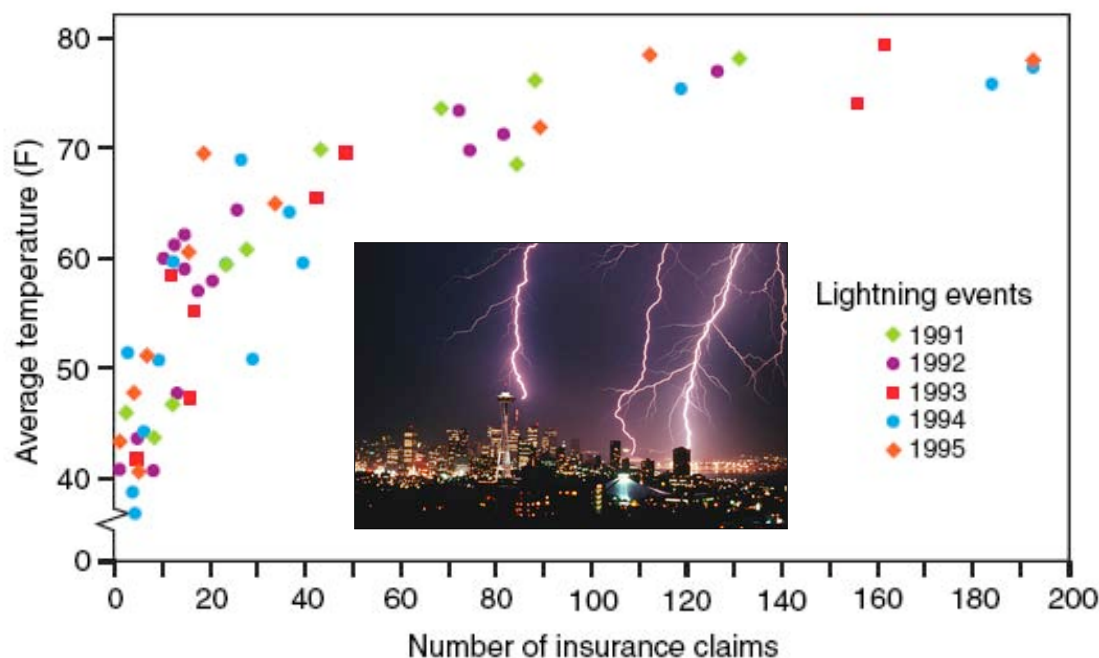


# Mudslide in El Salvador (2001)



# Fingerprint: Lightning

Lightning-related damages *accelerate* with temperature



Source: Hartford Steam Boiler Inspection and Insurance Co.

## Examples of Losses:

State Farm: \$330M/year in claims

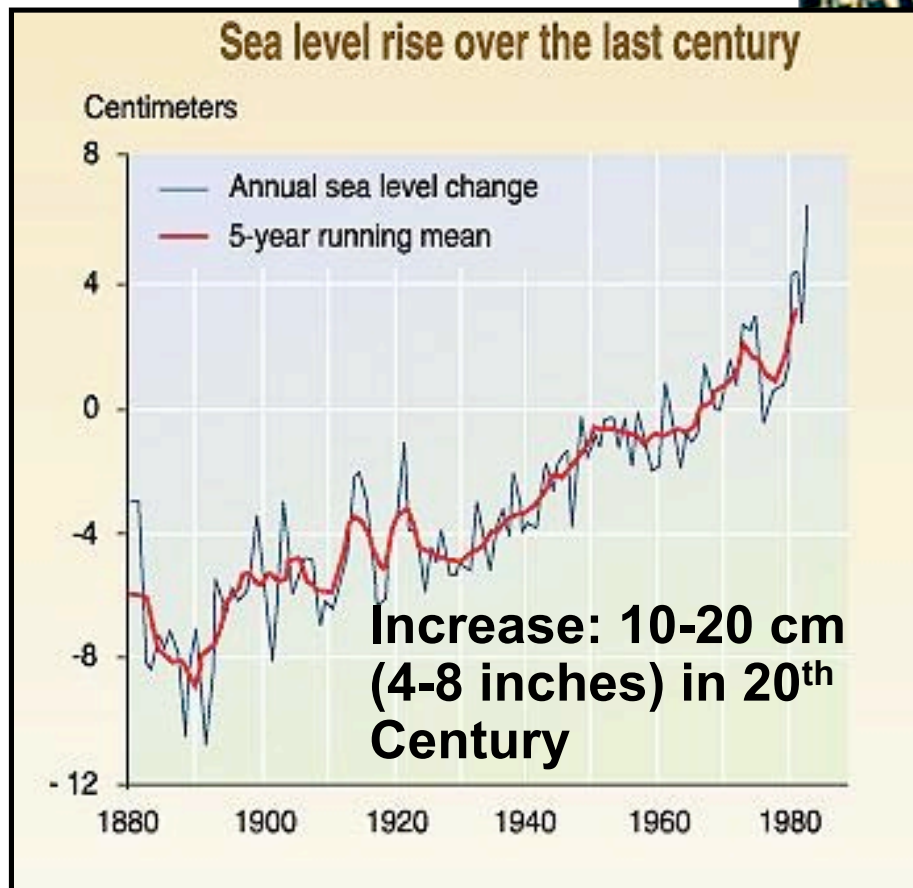
Factory Mutual: 3-4% of claims

- 50% wildfires in western US
- >3000/year: structural, vehicle fires
- 30% of power outages
- 80% of petroleum storage accidents
- 346 incidents, 81 nuclear sites: 1990s
- \$2B/year: airline operating costs
- 100,000/y: desktop computer losses
- Traffic signal outages

Source: [www.lightningsafety.com](http://www.lightningsafety.com)

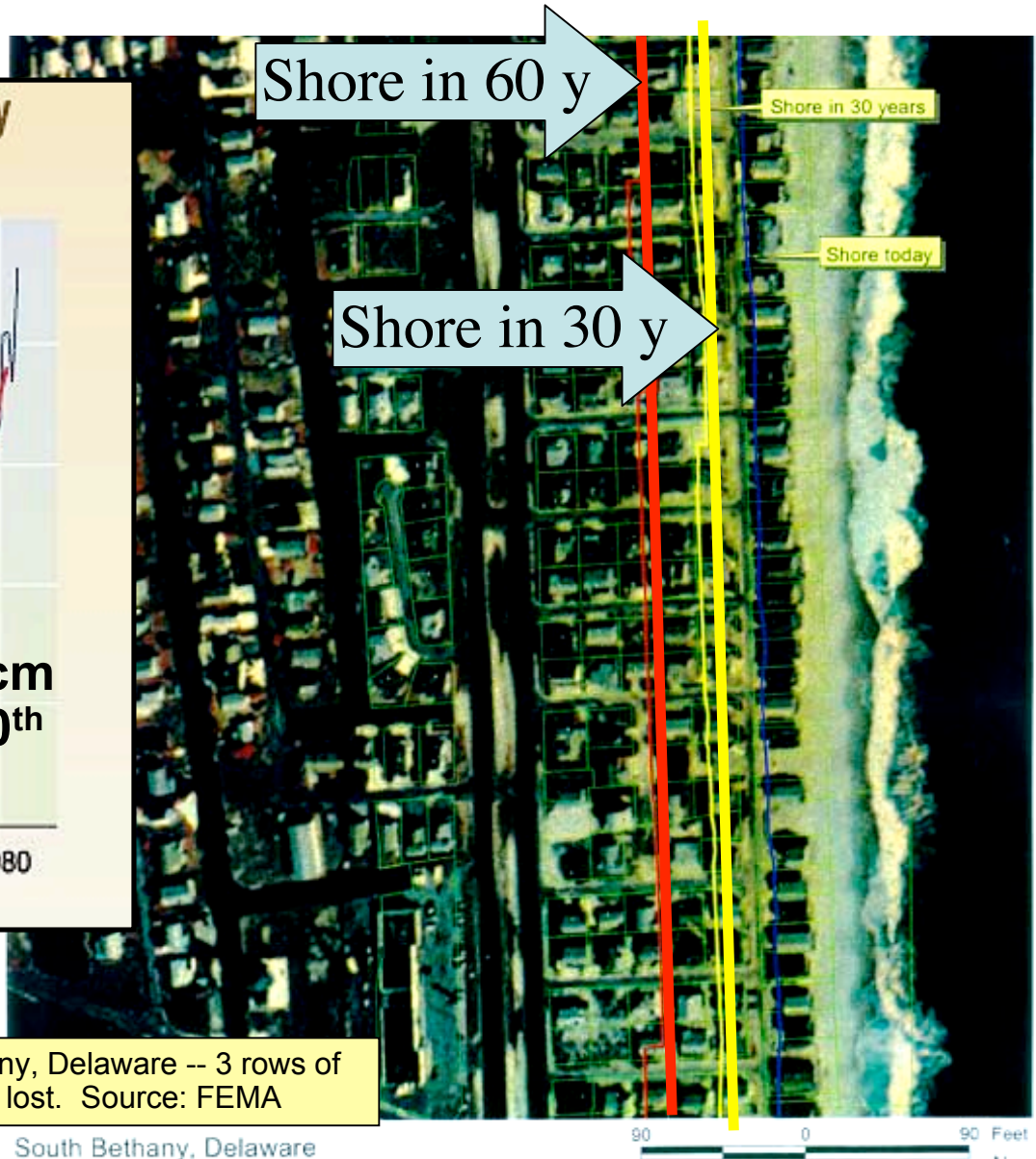


# Fingerprint: Sea Level Rise



3 feet displaces 200 million  
people globally

South Bethany, Delaware -- 3 rows of  
homes to be lost. Source: FEMA



# Fingerprint: Loss of Ice & Snow Cover

- Loss of land ice --> sea-level rise
- “Darkens” Earth’s surface
- “Freshens” oceans

NASA

NORTH  
POLE

Since 1979, more than  
20% of the Polar Ice Cap  
has melted away.

ARCTIC SEA  
ICE BOUNDARY IN 1979



# Harvard Expedition to North Pole



# Polar Bears are the Canaries in the Mineshaft



- Polar bears drowning in unprecedented numbers
- Reduced birth rates
- Extinction projected this century
- (Inuit hunters also impacted)







Photo Credit/Crédit photographique: Dan Crosbie



# Fingerprint: Systematic Worldwide Glacier Retreat

Americas

Europe

Asia

Africa

Australasia

Loss of world's  
glaciers = 1 1/2  
foot sea level rise

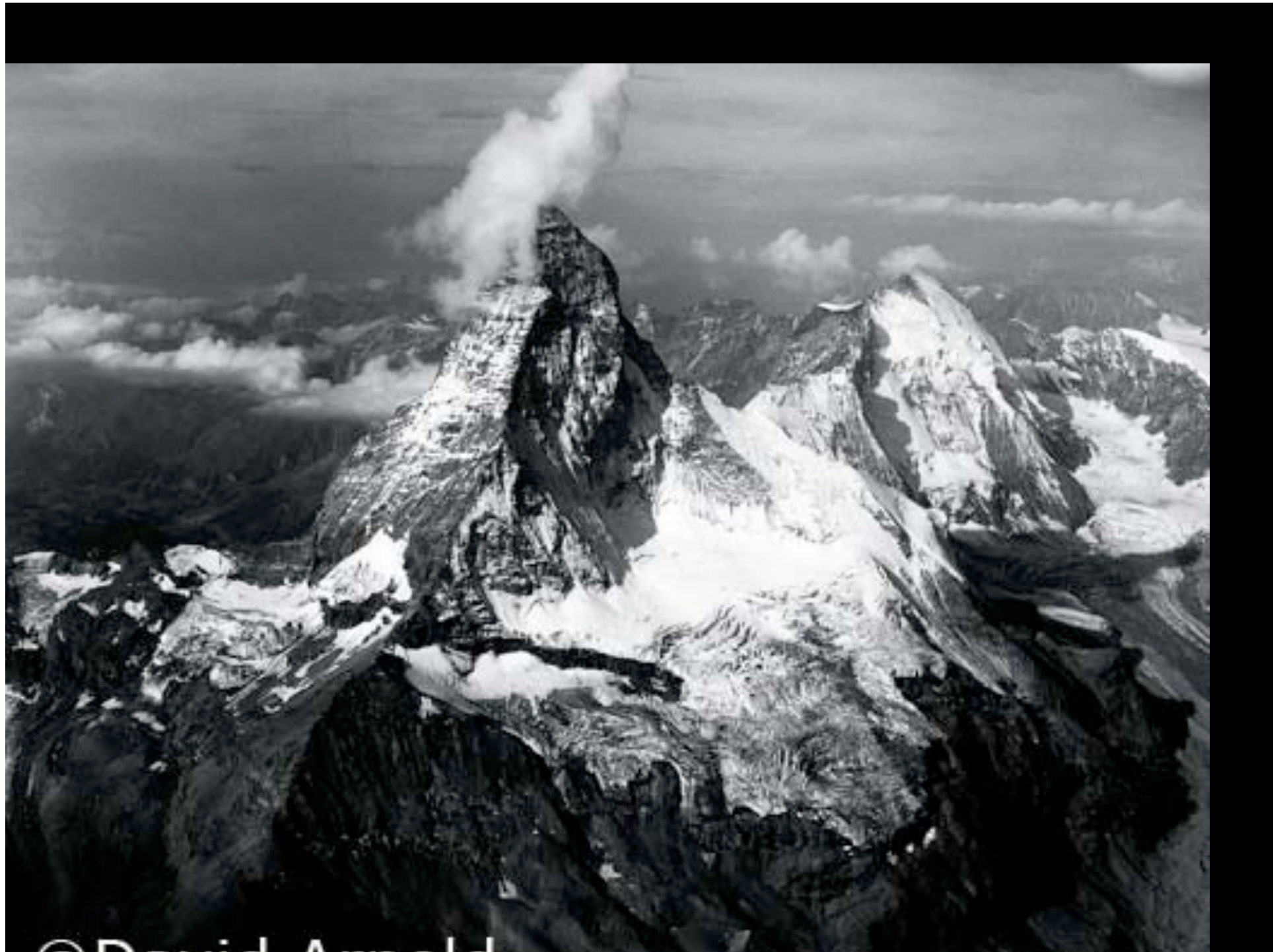
Grinnell Glacier  
“Glacier” National Park, USA



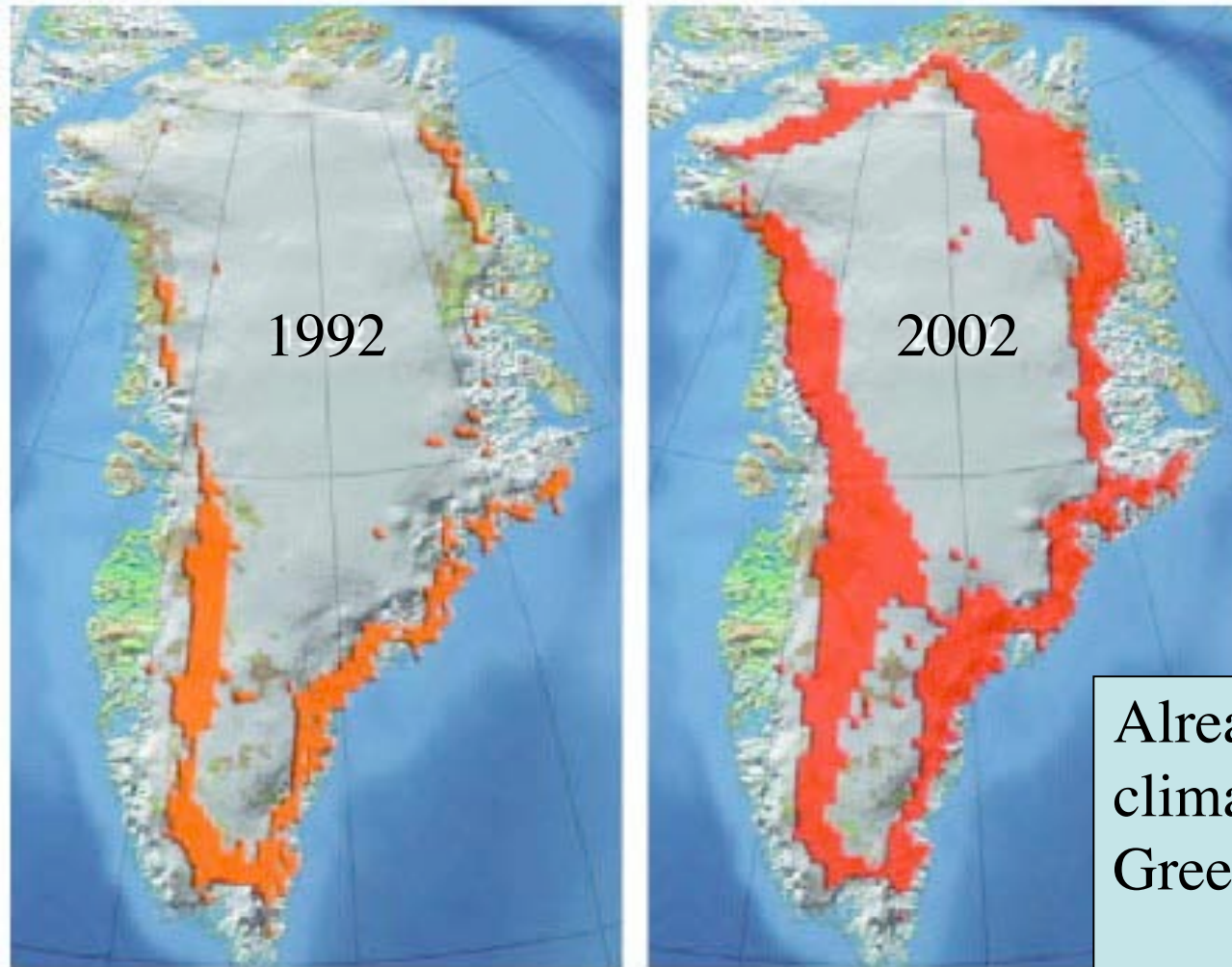
©Bradford Washburn







# The Greening of Greenland: 50 cubic miles of ice lost each year

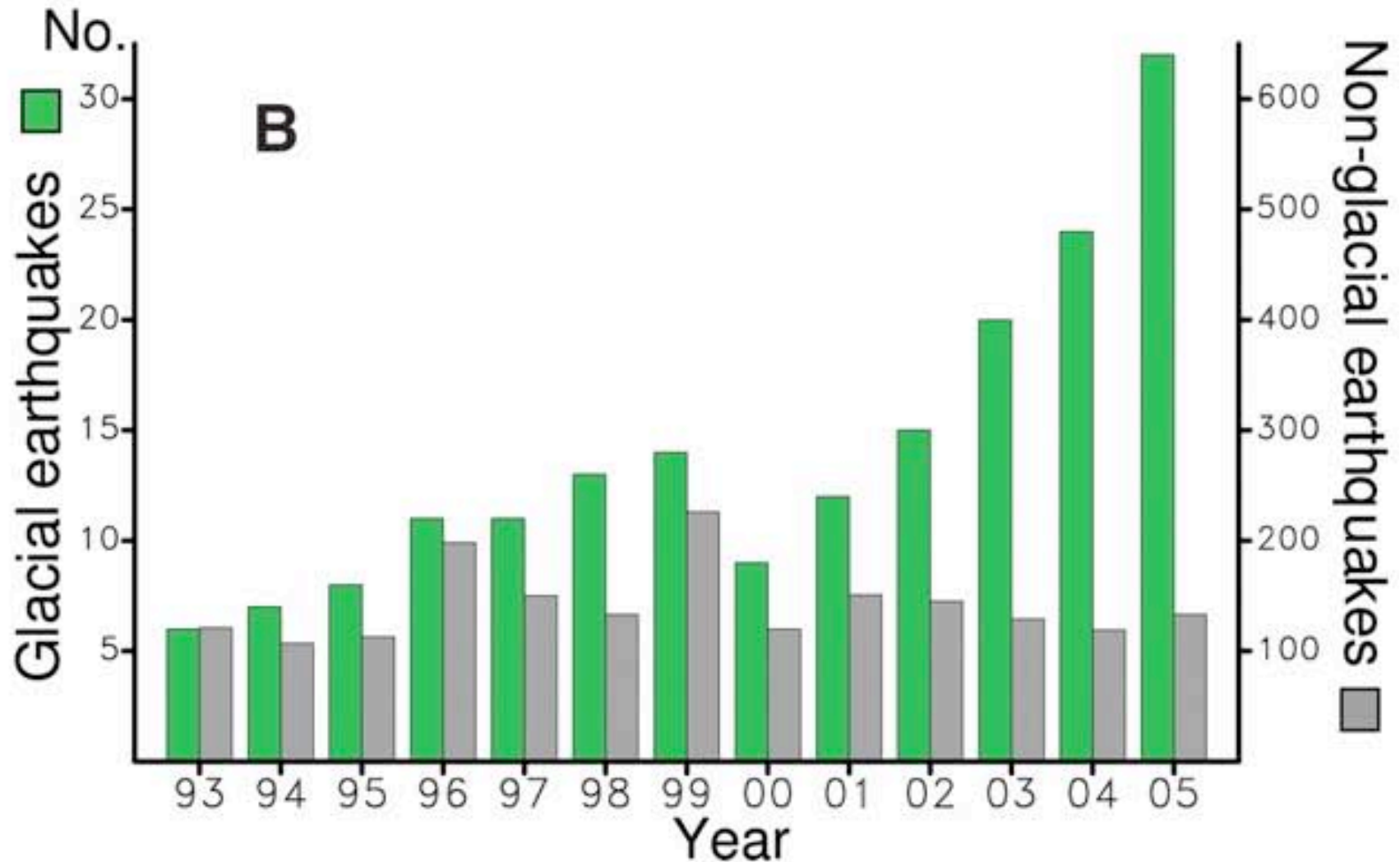


Source: Alley et al. *Science* (21 October 2005)

Already enough  
climate change to melt  
Greenland

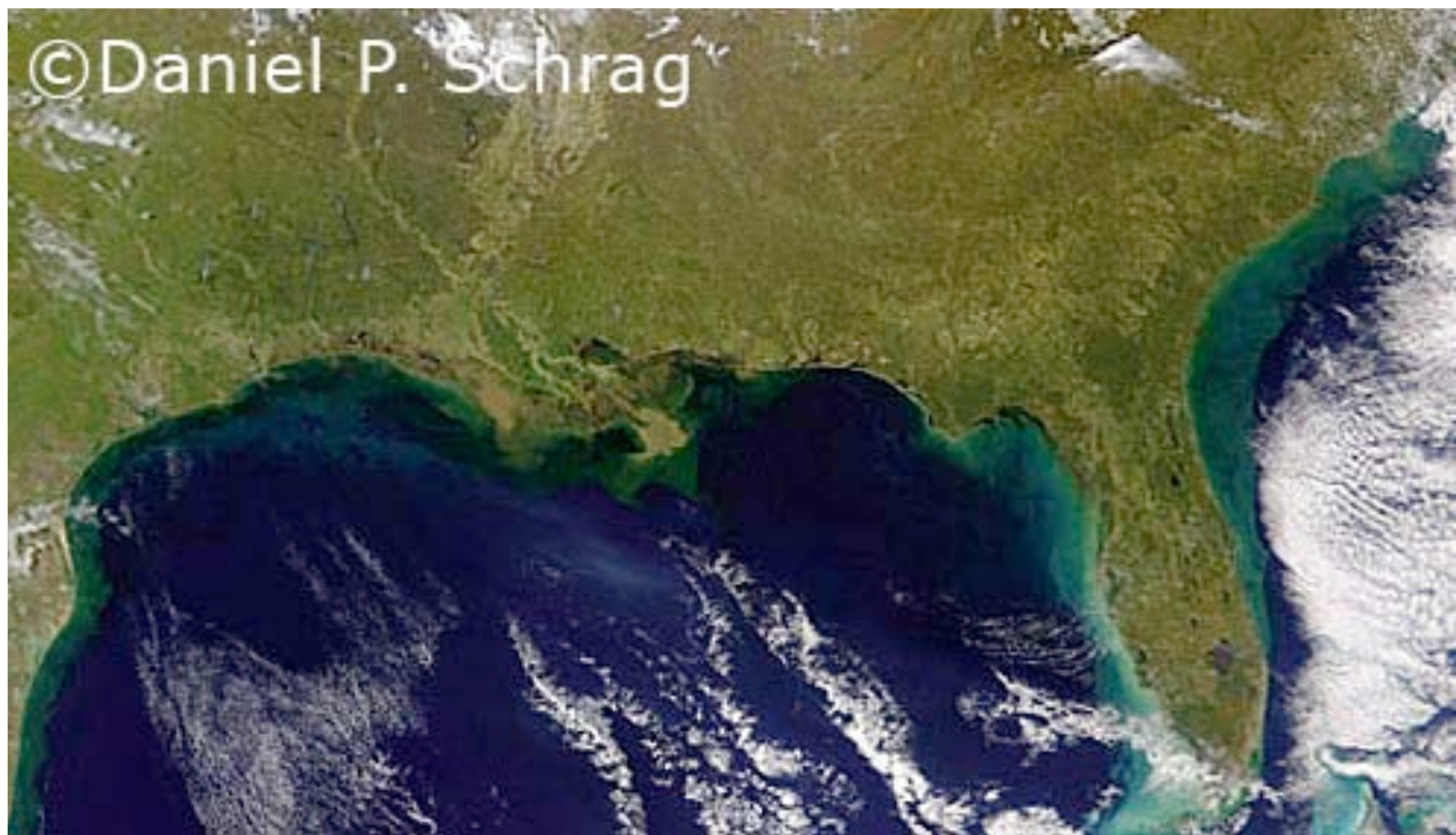
= 10 feet sea level rise

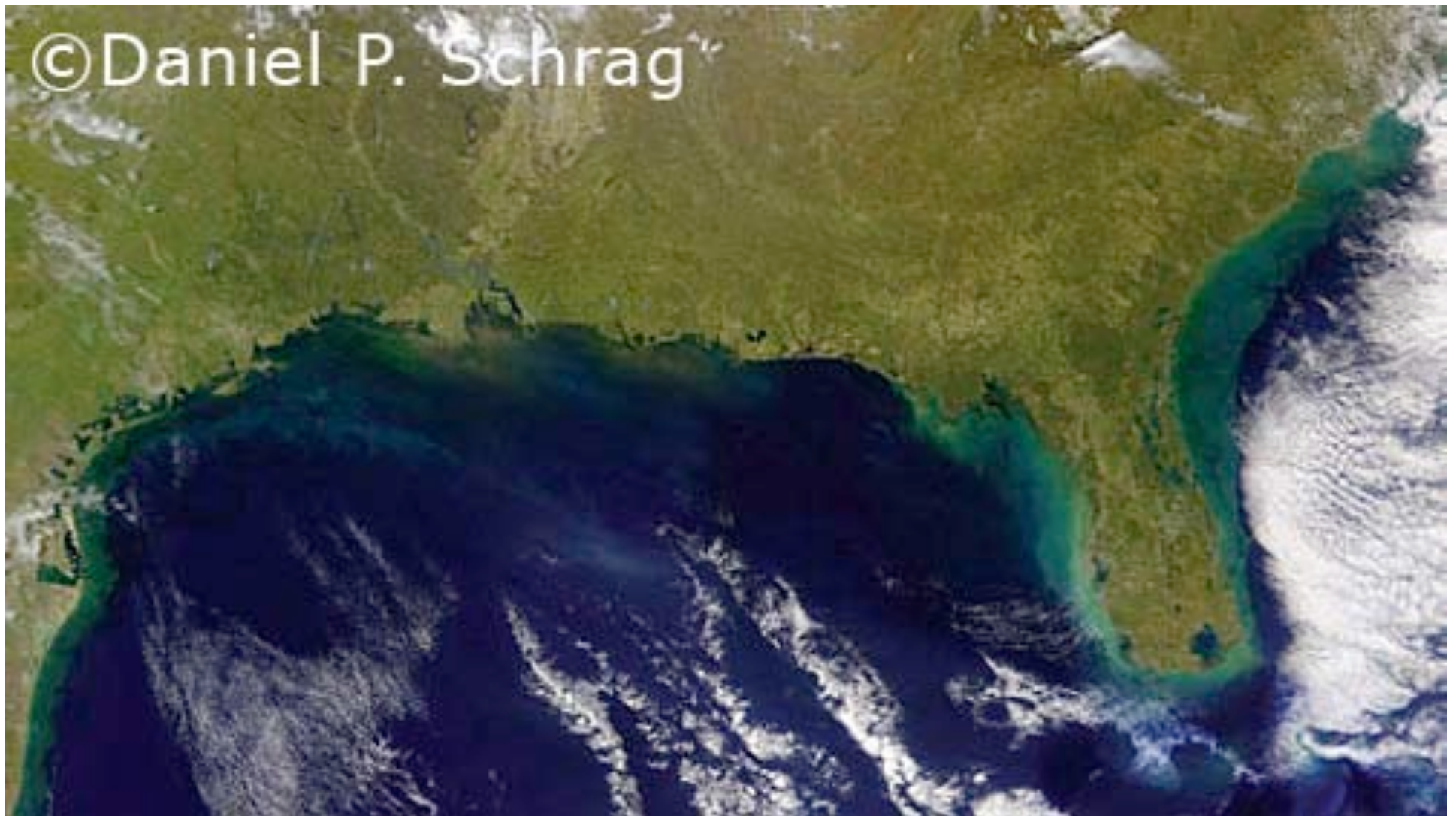
# Glacial Earthquakes on the Rise





©Daniel P. Schrag





Sea-level Rise for Half of Greenland Melting: ~2100  
(Source: Harvard University)







©Daniel P. Schrag



Harvard University  
Sea-level Rise for Half of Greenland Melting: ~2100

# Mt. Kilimanjaro (Tanzania)

1990



2000





The snows will be gone in 15 years

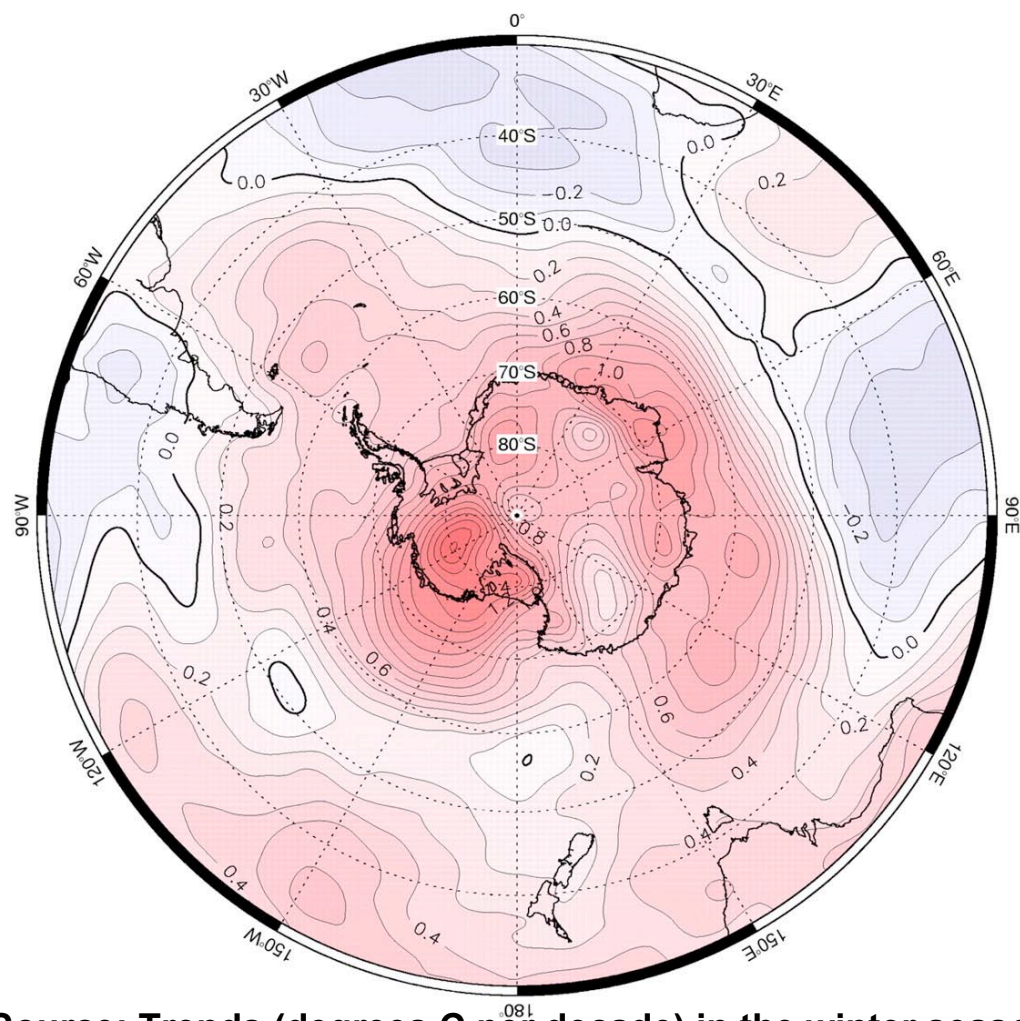




# Permafrost Disintegration



# Rapid Antarctic Warming



- First Antarctica-wide warming picture
- 1 degree Warming per Decade over past 30 years
- Warming 3x faster than world average

**Source: Trends (degrees C per decade) in the winter season 500-hPa temperatures from 1979 to 2001**

from the ECMWF reanalysis British Antarctic Survey J. Turner et al., *Science* 311, 1914 -1917 (2006)

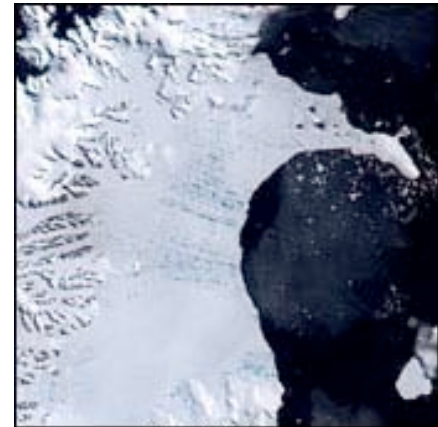
# Abrupt Climate Change

In the largest single ice sheet disintegration event in recorded history, approximately 3,250 square kilometers of the Larsen B ice sheet shattered in a five-week period in 2002.

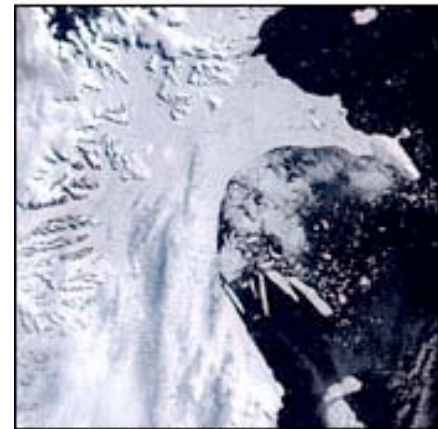
The disintegration released 720 billion tons of ice into the Weddell Sea.

Equal to area of Los Angeles Basin

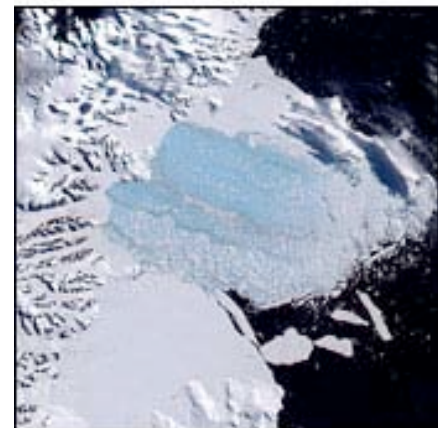
Source: National Snow and Ice Data Center



January 31, 2002



February 23, 2002



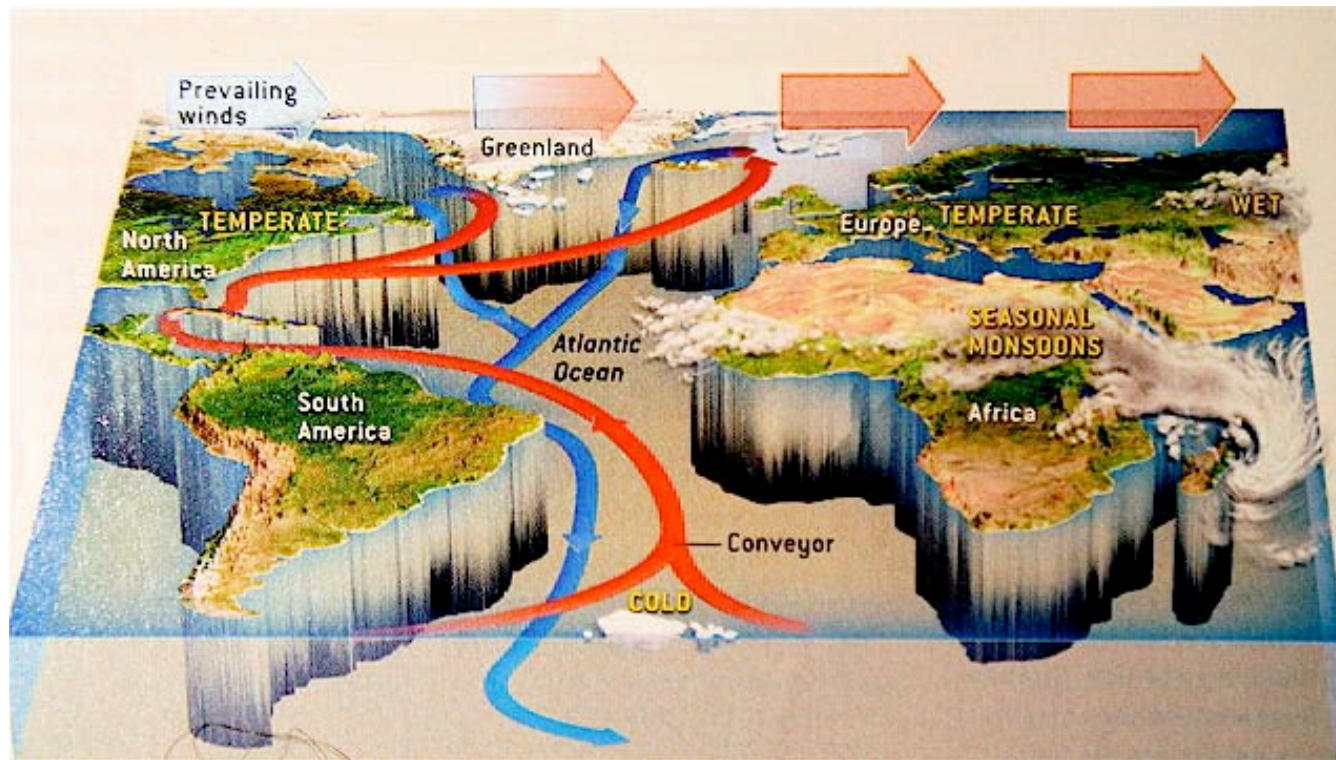
March 7, 2002



# *Abrupt Climate Change*

## The Ocean Conveyor Belt

Labrador and South England are same latitude

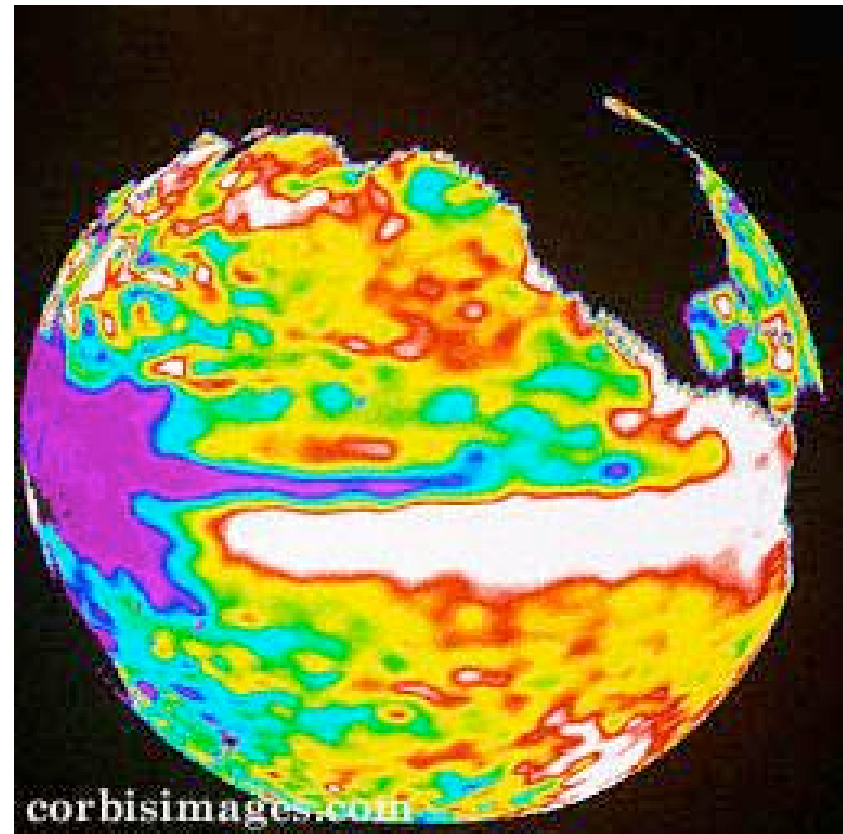


1998-2004 30% reduction in observed flow@ 25°NL

= Heat equivalent of 500,000 power plants (Source: Bryden et al. *Nature*)

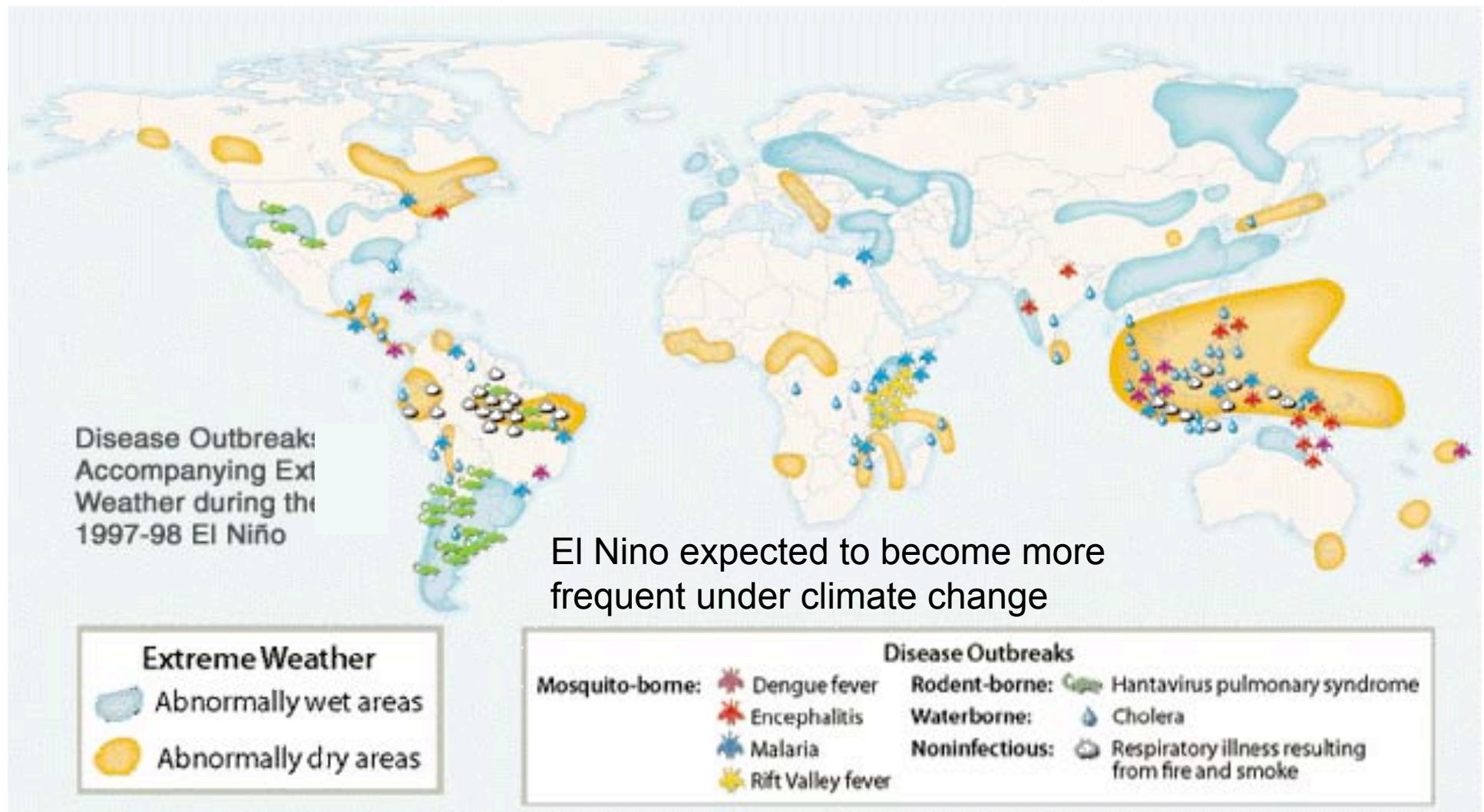
# Human Health Impacts

- **Human Systems**
  - Heat stress
  - Respiratory disease
    - Pollen
    - Mold
    - Smoke and particulates
    - Urban air pollution
  - Infectious diseases
  - Food poisoning
  - Water quality
  - Injury/death from disasters
  - Environmental contamination



*WHO estimates 150,000 human mortalities each year due to current climate change*

# Correlation of Disease Clusters with the 1997-1998 El Niño Weather Extremes

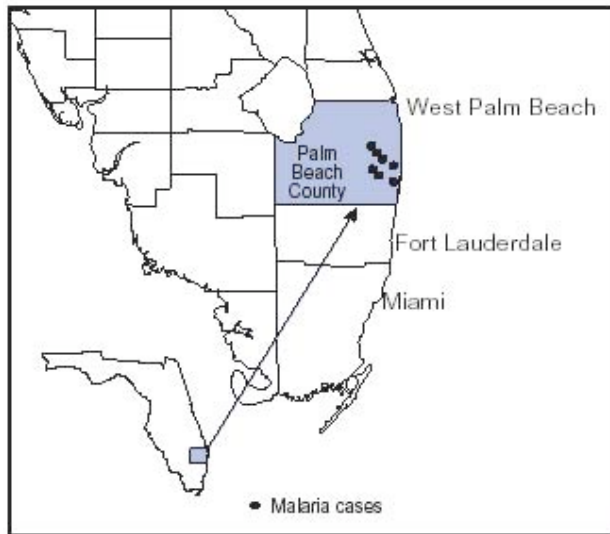


Source: Harvard Medical School, Center for Health and the Global Environment (*Science*)

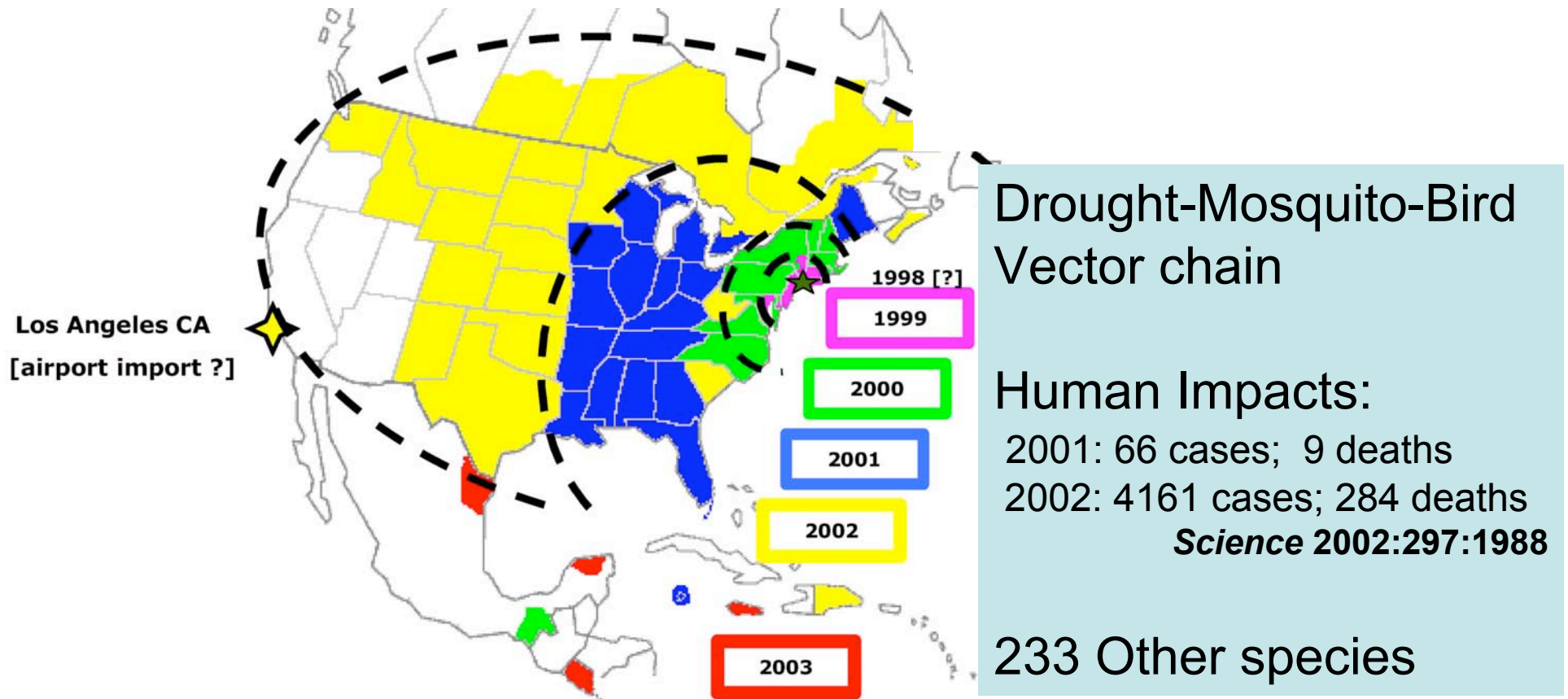


# Malaria in Florida (2003)

FIGURE. Location of cases of Malaria — Palm Beach County, Florida, July–August, 2003



# Spread of West Nile Virus in North America: 1999-2002



Sources: U.S. Army Environmental Programs Directorate,  
from Centers for Disease Control, Health Canada, USGS,  
and ProMED-mail as of 14 May 2003)



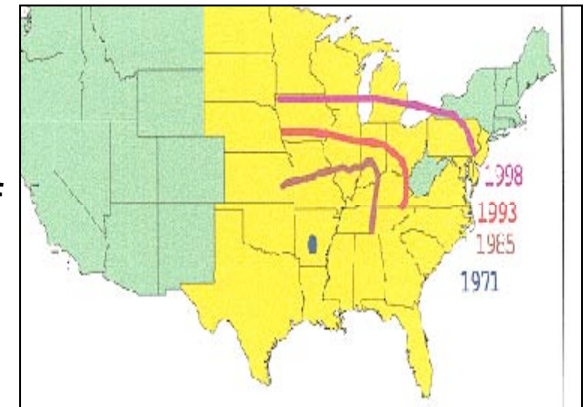
# Health Impacts on Non-Human Systems Are Economically Important



Pine beetle super-infestations: wildfire, lumber products, tourism/recreation, mudslides

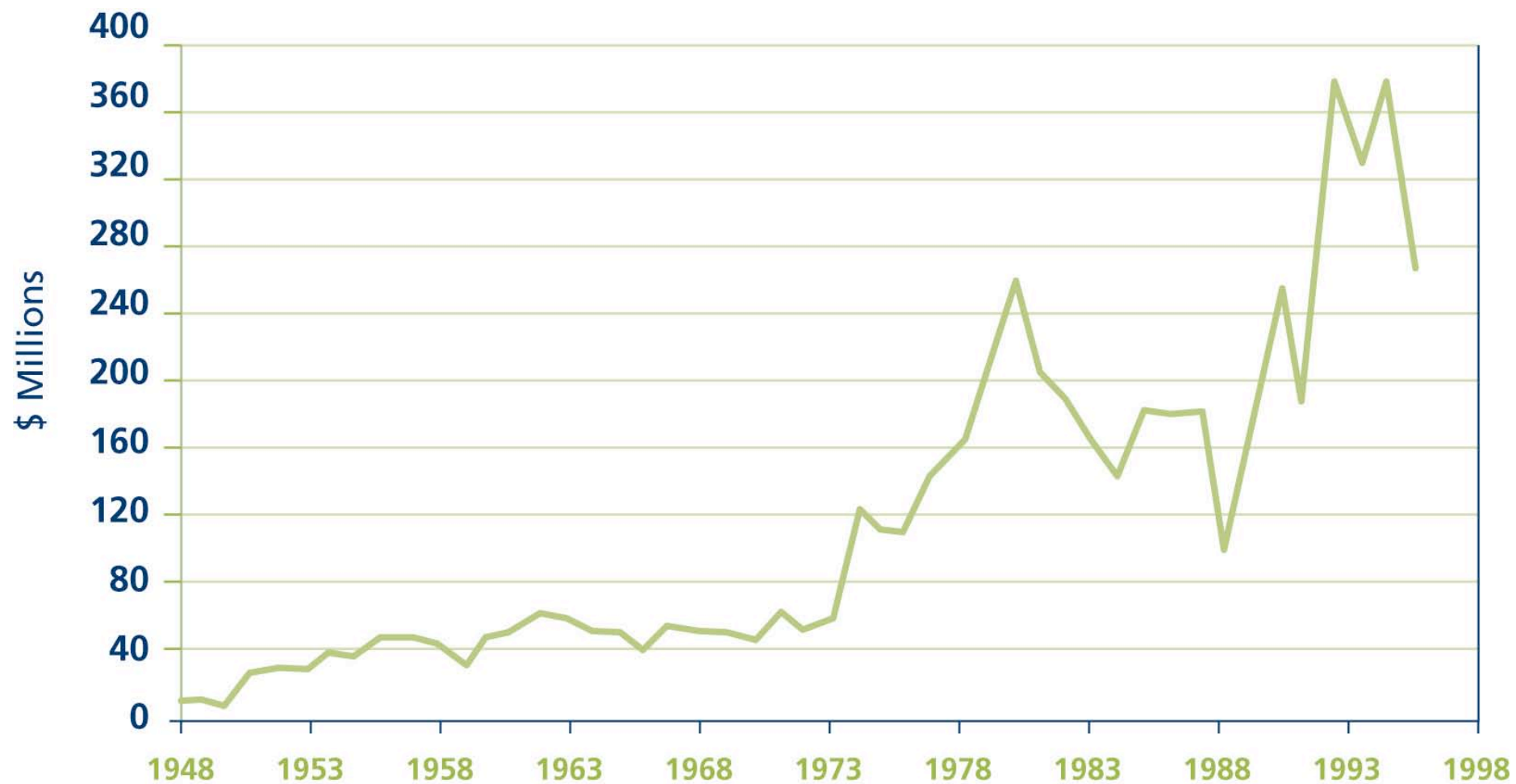


Crop Diseases: e.g.  
Expanding range of  
soybean rust: 1971-1998

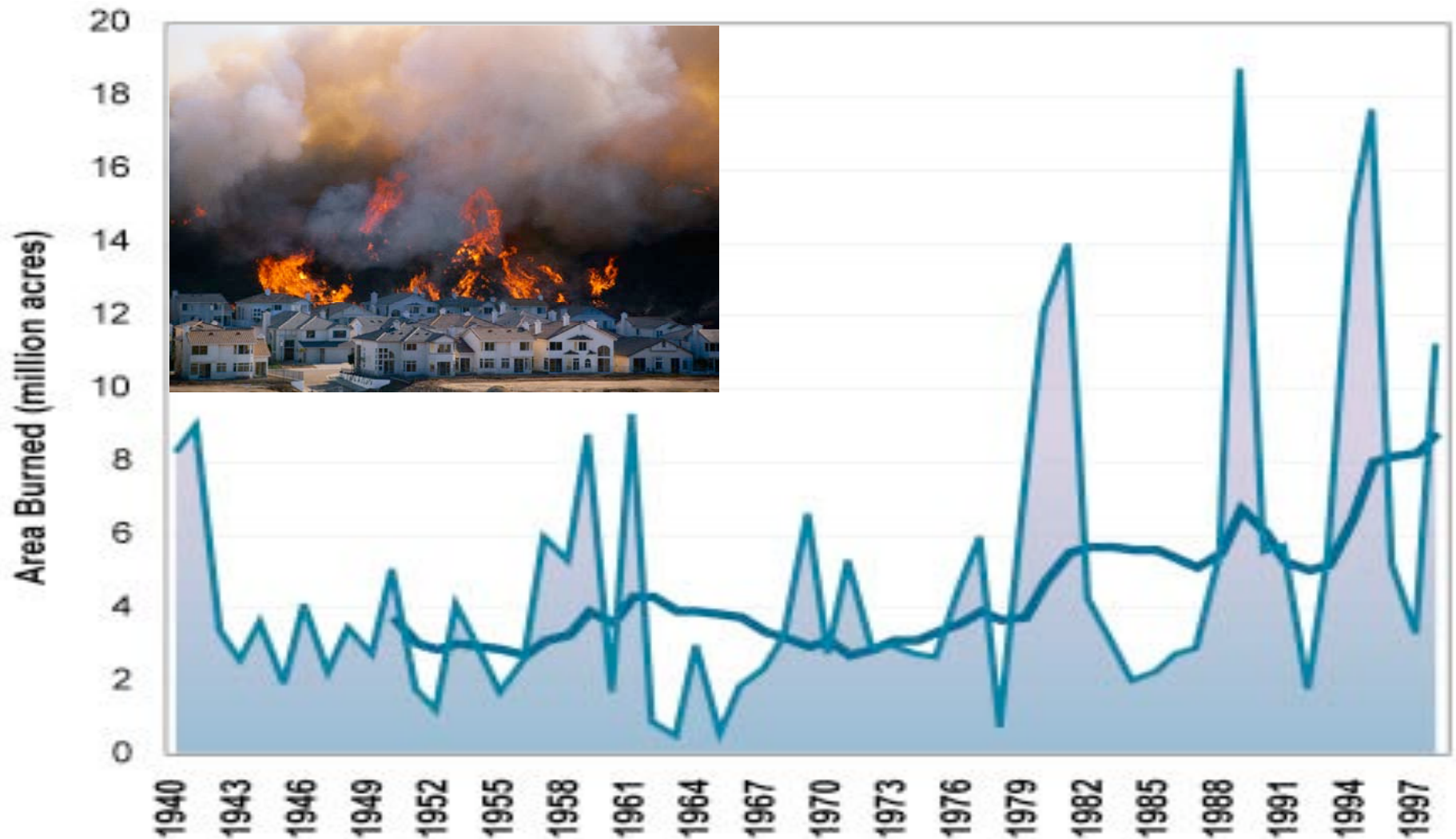


Coral bleaching: loss of  
pharmaceutical resources; coastal  
protection; freshwater salinization;  
fisheries

# Crop

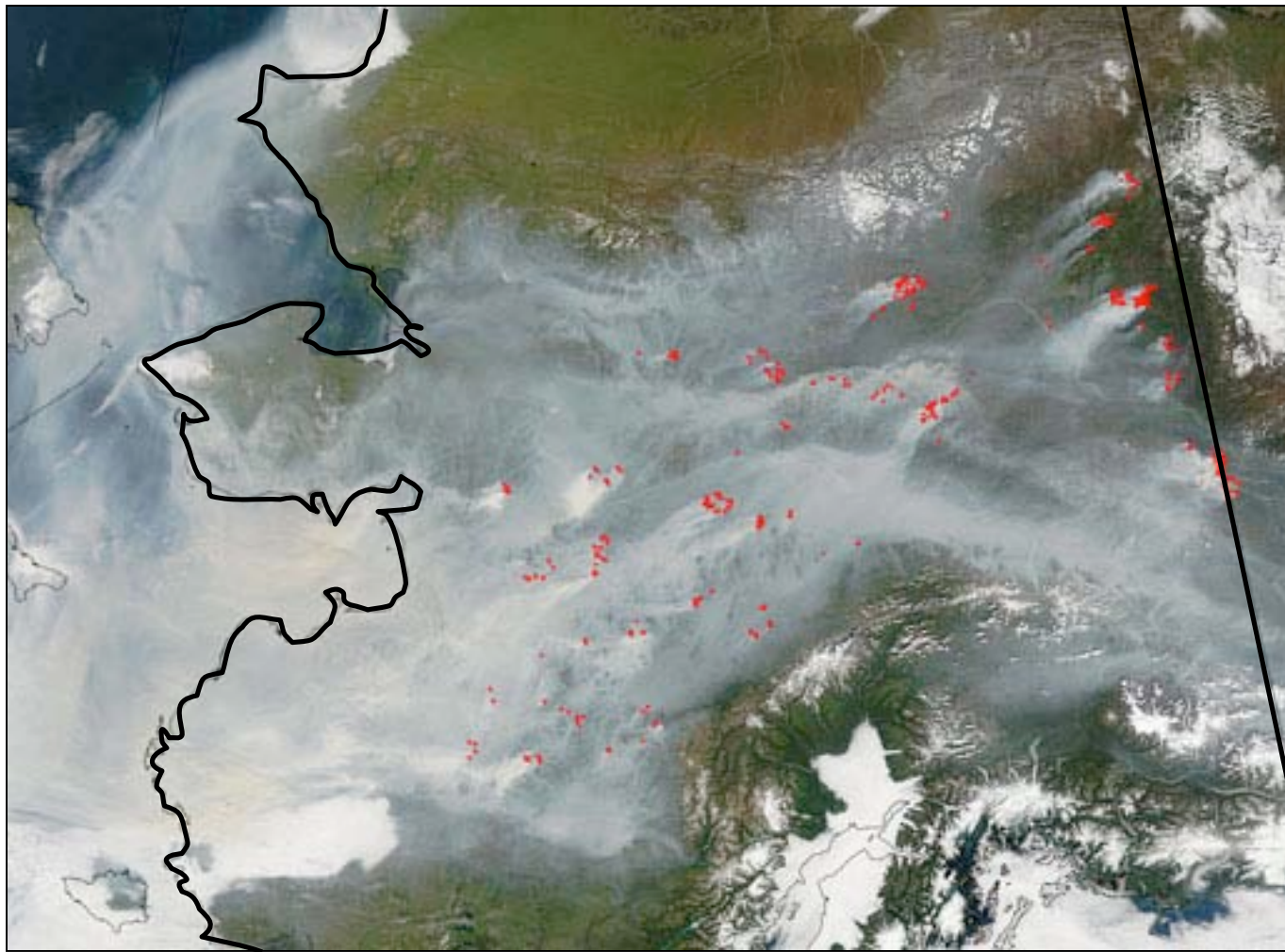


# Fingerprints: North America wildfire - area burned has doubled since 1970





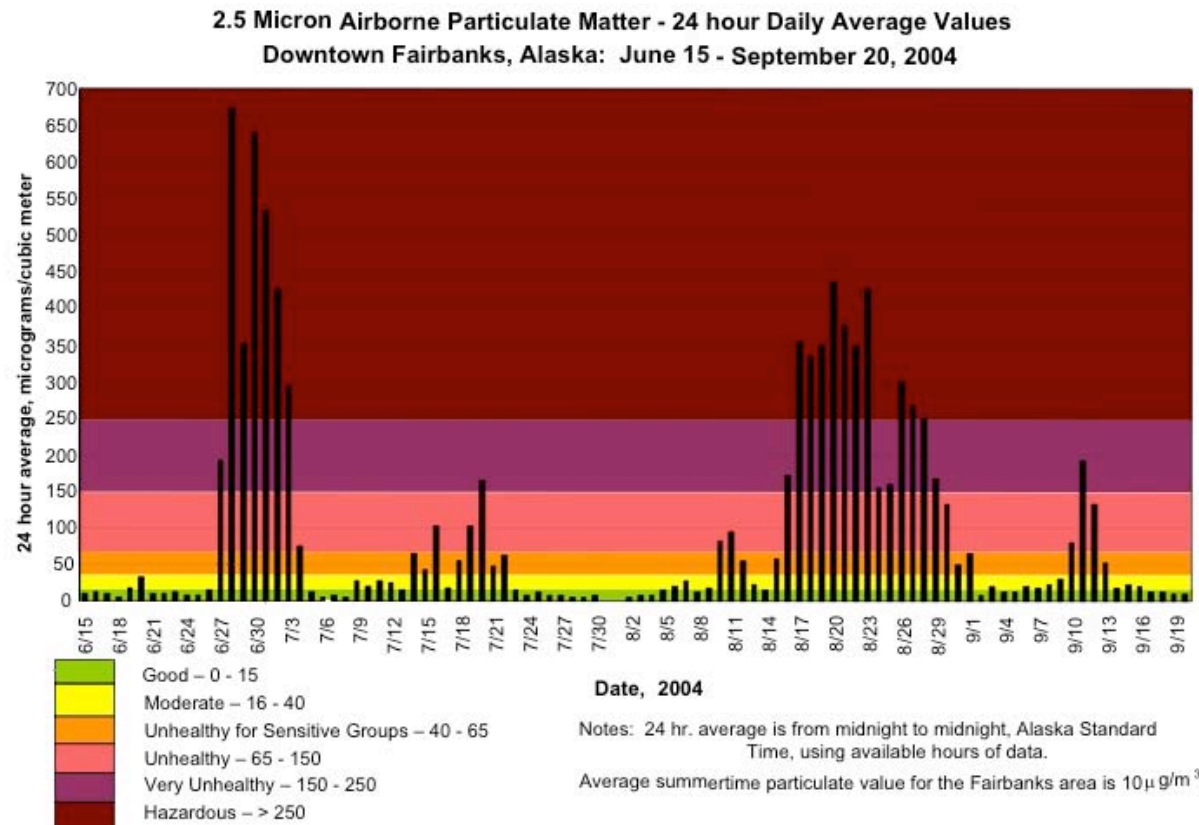
# Alaska: Summer 2004



Unhealthy air  
conditions over  
most of state

← 800 miles →

# Wildfire & Air-Quality Links: Alaska: Summer 2004



Fairbanks June 28, 2004



July 6, 2004



- *October was dry, hot.  
85-100°*
- *Fierce Santa Ana winds,  
up to 70 mph*
- *Humidity below 10-15%  
in many places*
- *14 fires*
- *Over 750,000 acres*
- *24 deaths, 246 injured*
- *3600 houses burned*
- *Cost over \$2 billion*
- *15,000 firefighters*











Copyright 1997 by David J. J. J.

# Idyllwild is More Vulnerable to Climate Change Impacts than Most Places

- Water quality/quantity
- Wildfire
- Power outages
- Forest loss/change
- Air pollution
- Loss of tourism
- Sensitive species





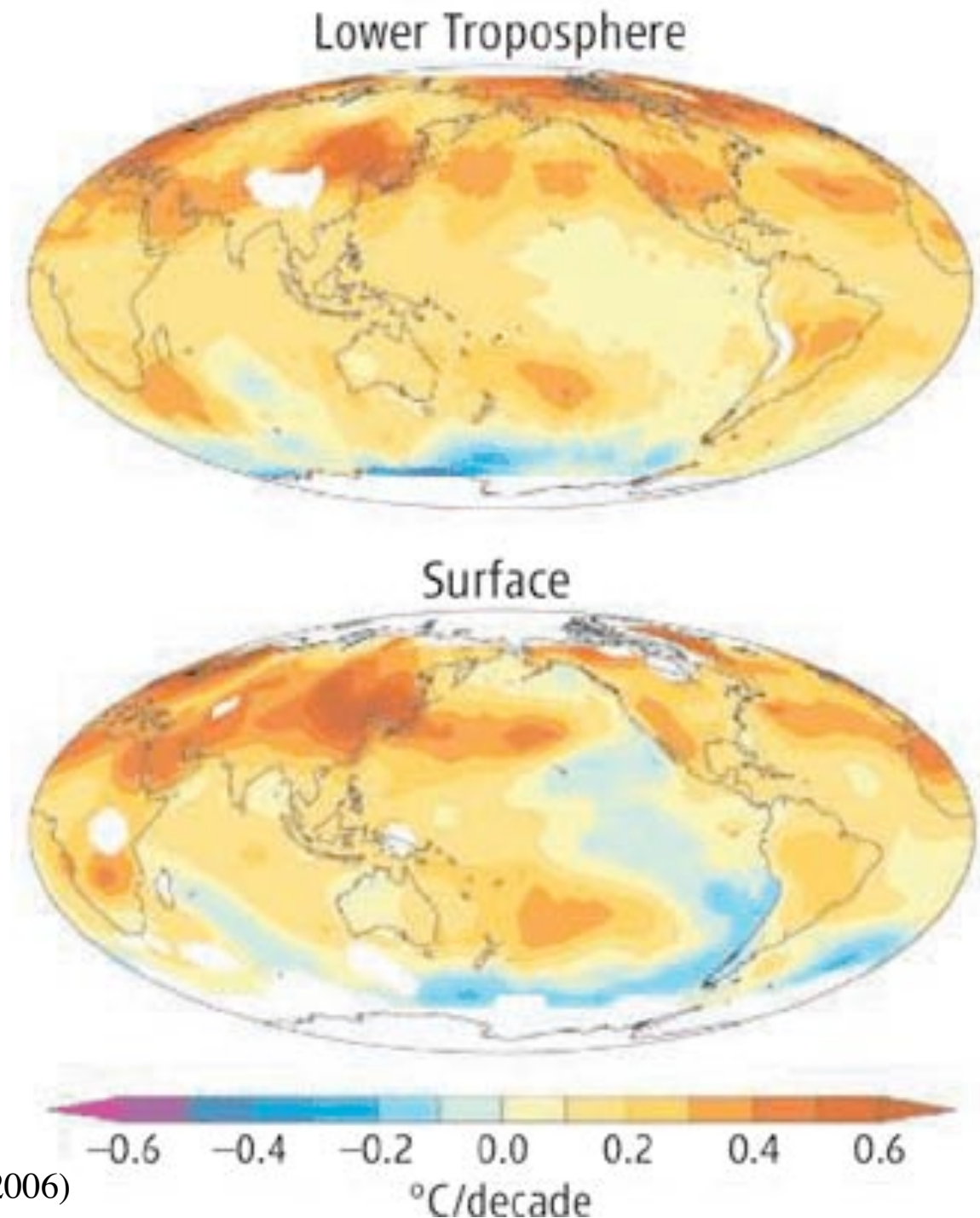
# Climate Skeptics are an Endangered Species





- Variability is a fact of life; but the dice are loaded
- No better alternative theory has been advanced
- Models predict past climate very well
- Risk management is the appropriate response

# Satellite data controversy resolved (May 2006)

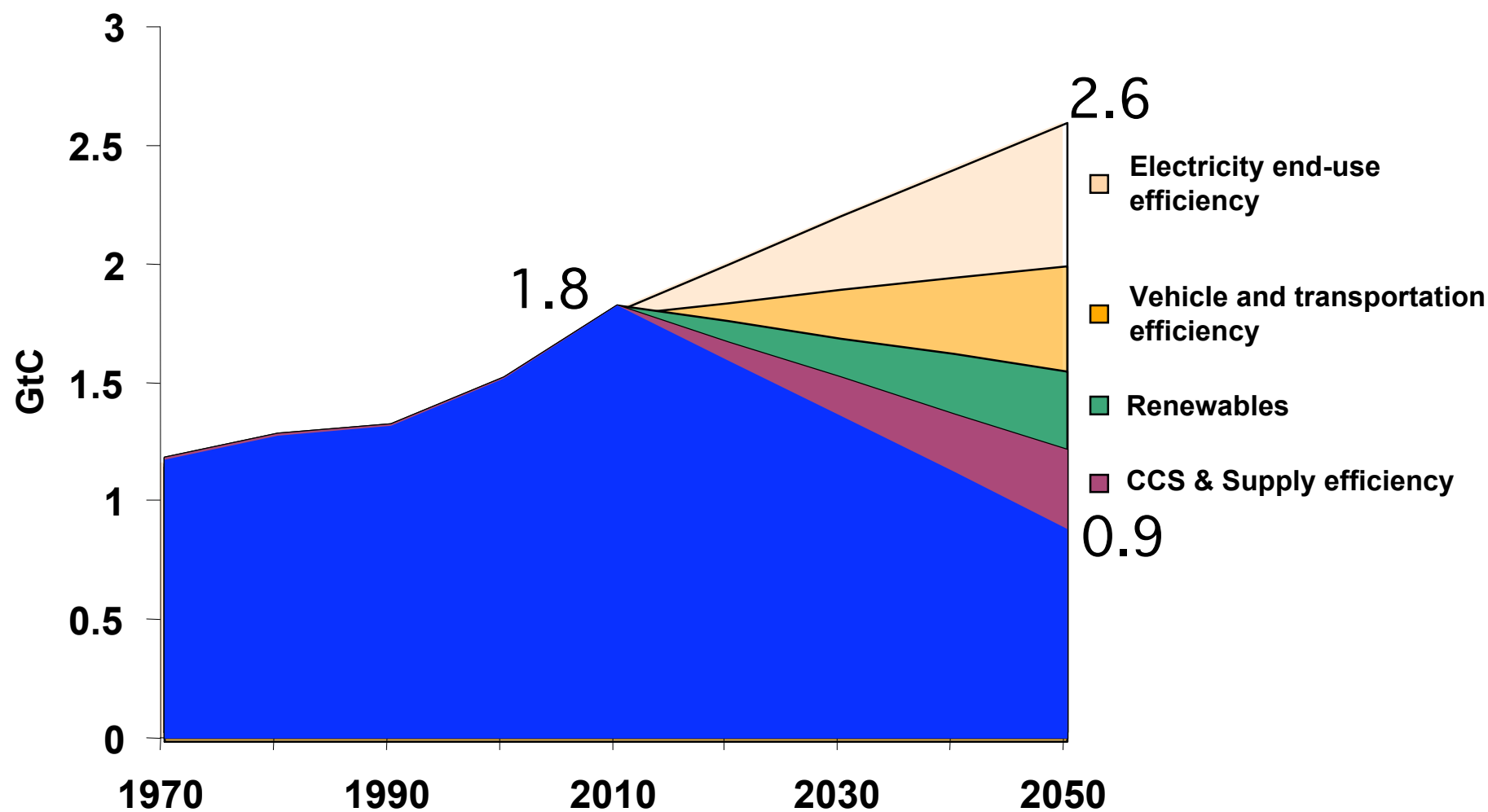


Source: Kerr, Science v312:825 (12 May 2006)





# Cutting U.S. Emissions in Half



After Pacala and Socolow (*Science*)

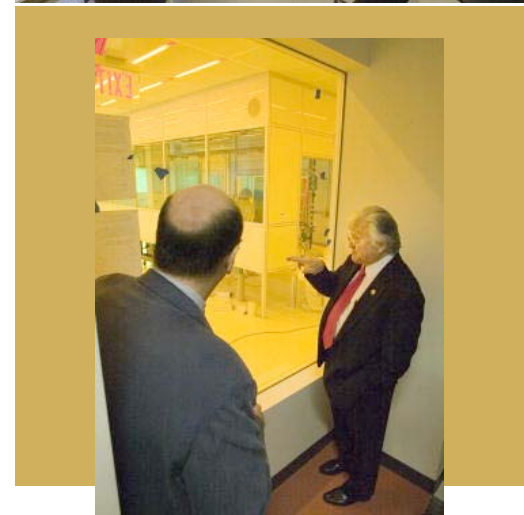
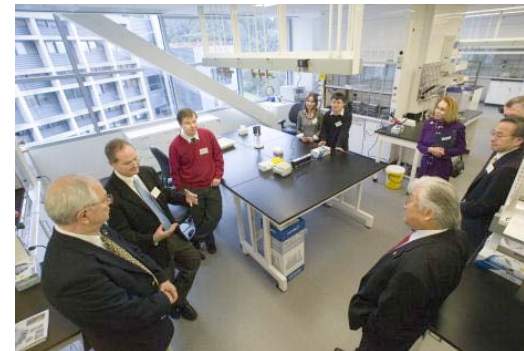
# Energy Efficiency is Mainstream

**Increased fuel economy will “*save jobs, save lives and save fuel.*”**

Bush Administration: April 27, 2006

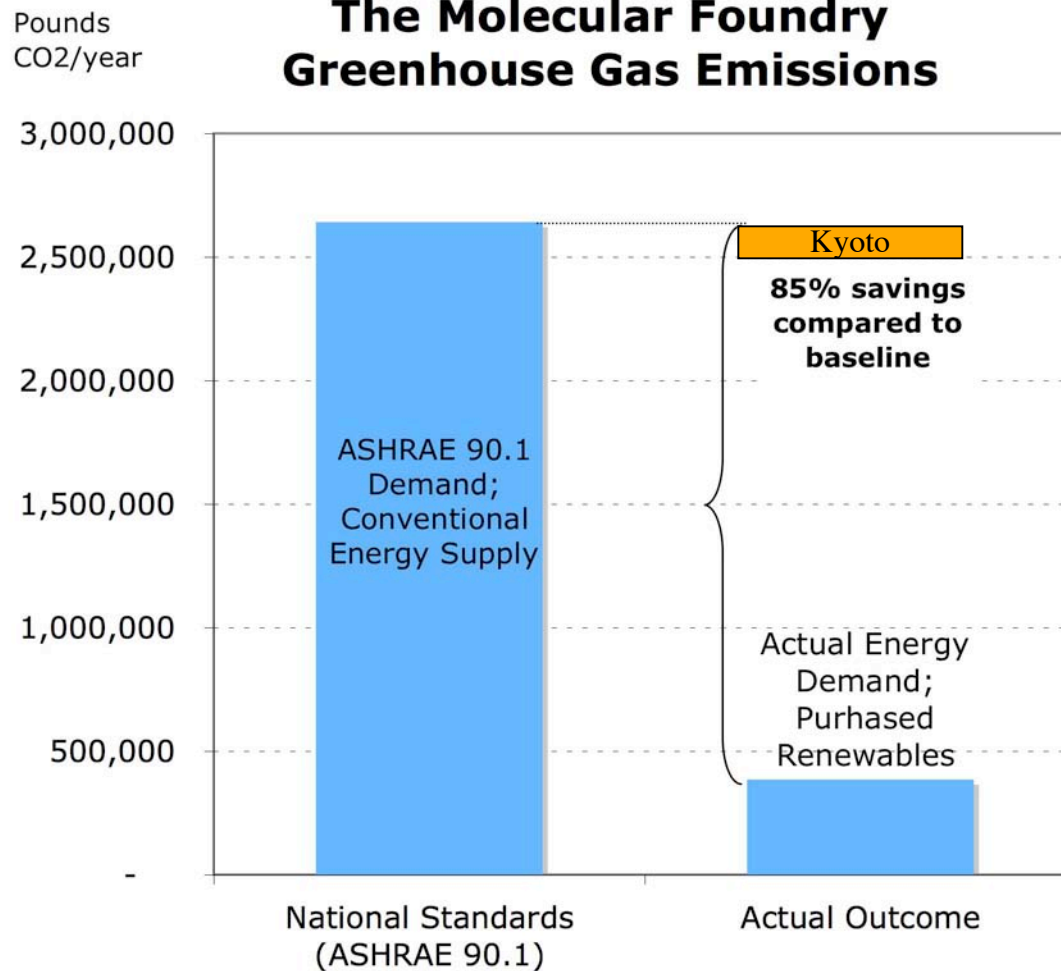


## The Molecular Foundry -- High-tech can be green





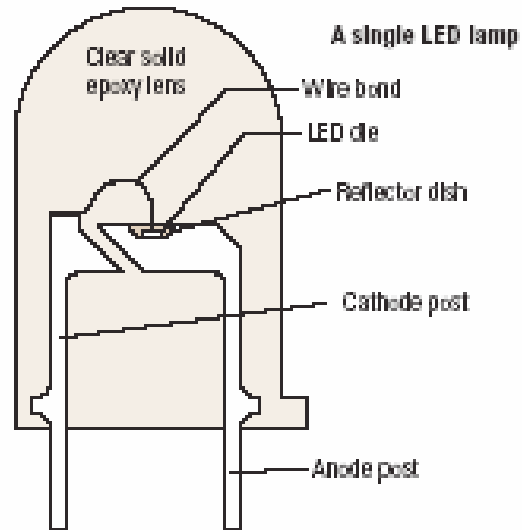
### **The Molecular Foundry Greenhouse Gas Emissions**



### **Scorecard:**

- ☐ **37% energy savings**
- ☐ **92% of electricity purchased from renewables**
- ☐ **85% greenhouse-gas reduction [Kyoto = 5%]**
- ☐ **35% indoor water savings and 65% outdoor savings**
- ☐ **Renewably grown bamboo floors**
- ☐ **Low-emission building materials**
- ☐ **LEED Silver (pending)**

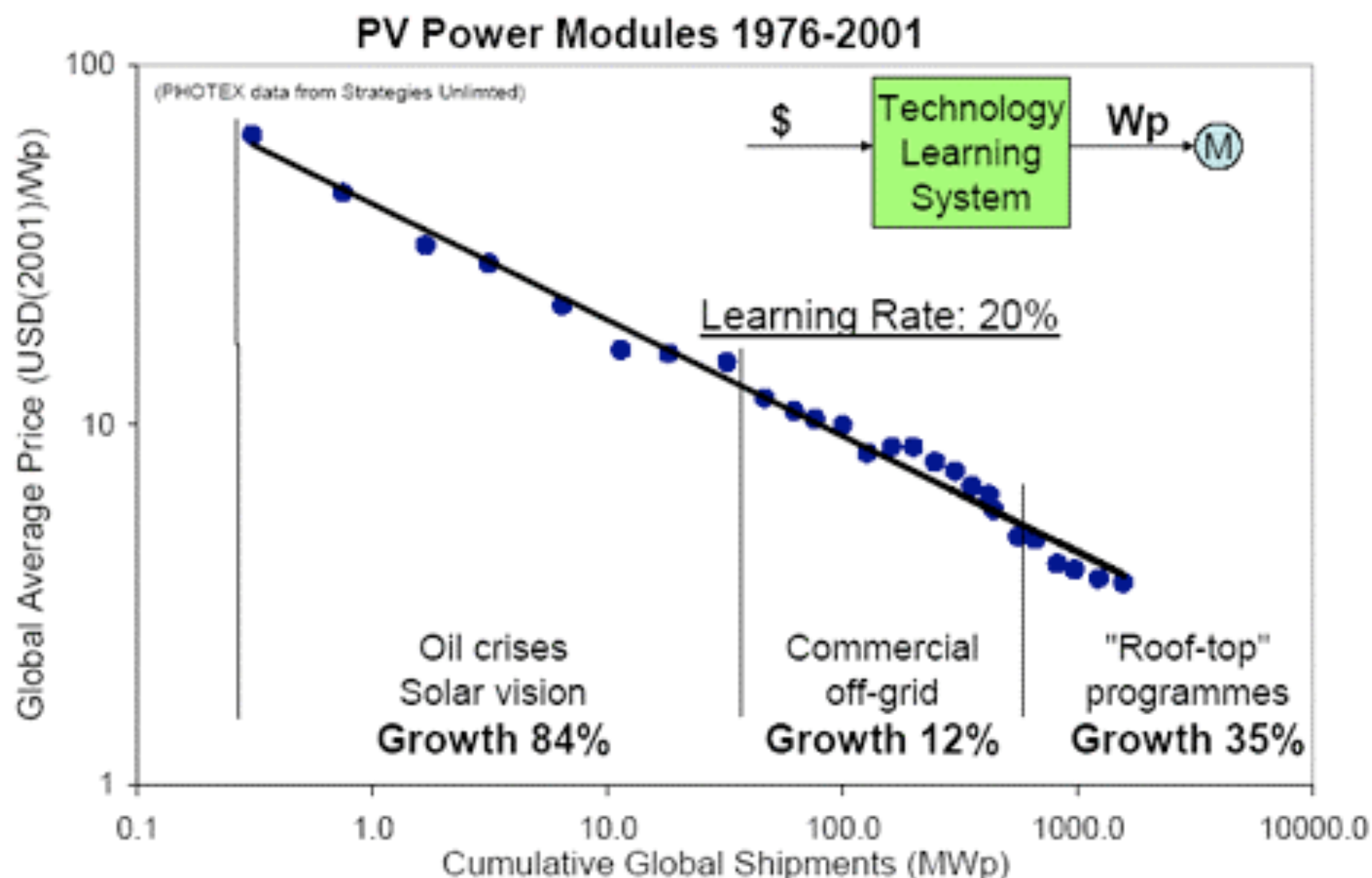
# Light Emitting Diodes



Source: Hewlett-Packard



## Stable Technology Learning over three decades and four orders of magnitude in spite of a deployment roller-coaster



# Fuel-based Lighting



**India:** street vendor



**Ghana:** lamp



**India:** propane lamp



**Bhutan:** merchant



**India:** sweat shop





**Tanzania:** night market



**China:** kerosene porter



**China:** kitchen



- **Kenya:** classroom light levels as low as 2% of western standards



- **Tanzania:** teachers grading homework with light levels 1% of western standards





million points of light



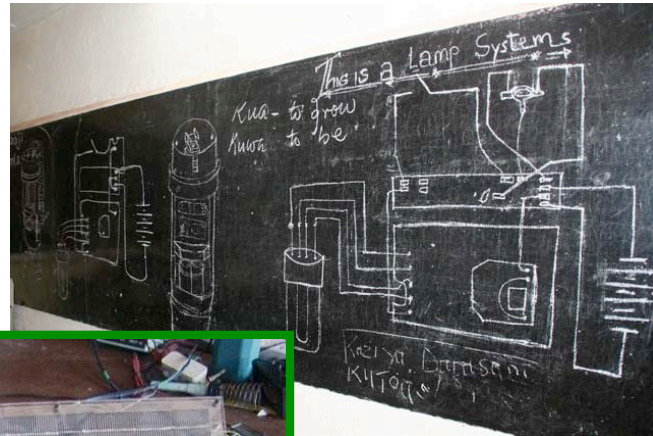


Kenya: vegetable stand in Kibera slum



Tanzania: shoe seller - flame [left]; white LED [right]





# http://HomeEnergySaver.lbl.gov

The Home Energy Saver - Mozilla

Back Forward Reload Stop http://hes.lbl.gov/ Search Print

Home Bookmarks Google Unisys Weather: Cur... National Hurricane ... Insurance and Clim...

## HOME ENERGY SAVER

The first web-based do-it-yourself energy audit tool

Click here to give us your feedback and help us to improve this site.

Save \$\$\$ Find out more about the profitability of energy efficiency upgrades

**ENERGY EFFICIENCY**

Investing in a home on your street could be more profitable than investing on Wall Street.

**MAKING IT HAPPEN**  
Find resources to make your home more energy efficient.

Money isn't all you save. Visit the ENERGY STAR website for information on energy-efficient products.

Developed by the Environmental Energy Technologies Division at the Lawrence Berkeley National Laboratory

Disclaimer | Privacy Statement | HES Mission Statement Sponsors

**CALCULATOR**  
Find the best ways to save energy in YOUR home!

Enter your zip code: 94720 Enter previous session #

Go!

Don't know the zip code?

Your Home Energy Saver Results - Mozilla

Back Forward Reload Stop http://hes3.lbl.gov/hes/status Search Print

Home Bookmarks Google Resume DC Power for Data C... File Transfer HESBugs.taf

## Home Energy Saver

Making It Happen

Help us improve the site. Click here

About HES What's New Energy Librarian Glossary FAQ Search Help

General Info Heating & Cooling Water Heating Major Appliances Small Appliances Lighting

Session ID: 566483  
Zipcode: 92549  
Location: Idyllwild, California

### Initial Results: Your Energy Bill (\$/year)

Existing Home \$1340  
with Selected Upgrades \$759

	Heating	Cooling	Water Heating	Major Appliances	Lighting	Small Appliances
Existing Home	\$ 411	\$ 9	\$ 182	\$ 429	\$ 152	\$ 157
With Selected Upgrades	\$ 169	\$ 9	\$ 100	\$ 233	\$ 91	\$ 157

Instructions | Existing Home Configuration: View | Change

View or Modify Upgrade Details View Upgrade Report

### Selected Upgrade Package for your Home

Upgrades Requiring Investment

1. Thermostat
2. Electric clothes dryer
3. Indoor lights
4. Dishwasher
5. Gas water heater
6. Clothes washer
7. Duct Sealing
8. Refrigerator
9. Wall insulation
10. Air sealing
11. Windows
12. Gas furnace
13. Attic insulation
14. Slab insulation
15. Ceiling fan
16. Duct Insulation
17. Cool roof

Comparing Results to your Utility Bill | See typical costs of running various appliances

### Potential Annual Savings

Money:	\$581
Energy:	2,271 kWh & 302 Therms
CO <sub>2</sub> Emissions:	3,921 lb. CO <sub>2</sub>

More detail on energy and CO<sub>2</sub> emissions...



Thank You



EMills@lbl.gov



# Thank You



EMills@lbl.gov